Technical Report Series

Nipigon Bay Walleye Historical Review

Technical Report #9
Nipigon Bay

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REMEDIAL ACTION PLANS

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Remedial Action Plan
Plan d'Assainissement

Nipigon Bay

November 1, 1991

To Whom it may Concern:

The following report identifies the major sources of stress responsible for the decline of the Nipigon Bay walleye population. An understanding of these stresses is necessary in developing a strategy to successfully rehabilitate this population..

The author notes that the walleye decline in Nipigon Bay and the subsequent collapse of this population were primarily due to a combination of: exploitation, pollution, changes in walleye habitat, and the introduction of exotic species.

Nipigon Bay walleye have supported a sport and commercial fishery since the time of the fur traders. However, all commercial fishing activity in Nipigon Bay ceased in 1984 and the Nipigon Bay and River recreational walleye fishery was closed in 1989 to facilitate rehabilitation efforts. Effluent entering Nipigon Bay from the Red Rock pulp mill may have created a barrier to walleye travel corridors between Nipigon Bay and Nipigon River spawning areas. Similarly, changes in Nipigon River water levels and conditions due to deforestation, damming and industry have decreased spawning opportunity and success. The author points out that this aquatic system has undergone vast changes over the years and many of the parameters which limited walleye abundance in the past have been reduced or, in some cases, eliminated.

This report is one of a series of technical reports on the aquatic ecosystem in northern Lake Superior. This series is being prepared in support of the Remedial Action Plan program which was initiated by the International Joint Commission in 1986.

Sincerely,

Ken Cullis
Coordinator
Nipigon Bay Remedial Action Plan

:rmb
Attach:

NIPIGON BAY
WALLEYE
HISTORICAL REVIEW

A Report to:
The North Shore of Lake Superior
Great Lakes Cleanup Fund Program

Prepared by:
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November 1991

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This report was prepared for The North Shore of Lake Superior Great Lakes Cleanup Steering Committee:

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PREFACE

The importance of aquatic habitat remediation in northern Lake Superior was identified early in the Remedial Action Plan (RAP) process. As a result, when Environment Canada announced the Great Lakes Cleanup Program in the spring of 1990, a Lake Superior RAP Team subcommittee was formed to coordinate the submission and implementation of habitat restoration projects in the Thunder Bay and Nipigon Bay AOCs.

The Nipigon Walleye Historical Review was initiated by the habitat subcommittee in support of the project "Habitat Restoration and Inducement of Self-Sustaining Fish Stocks - Nipigon Bay AOC 1990 - 94". Financial support for the investigation was provided by Environment Canada through the Great Lakes Cleanup Fund. Additional support was provided by the Nipigon District of the Ontario Ministry of Natural Resources.

This technical report series was commissioned in support of the four Areas of Concern within the Lake Superior RAP Program. The Great Lakes RAP Program was initiated by the International Joint Commission in 1986.

EXECUTIVE SUMMARY

This report was undertaken as part of an effort to rehabilitate the drastically reduced walleye populations in Nipigon Bay, Lake Superior. Important changes in the area are identified as are possible impacts on the local walleye population. The traditional spawning sites in Nipigon Bay as noted in the literature and from information gleaned from local residents have been documented. Stocking and rehabilitation programs to date are also included.

The factors affecting fisheries, from the arrival of the first settlers to present day influences are many and varied. The effects of commercial and sport fishing, the logging industry, and sea lamprey control methods are noted as to their impact on the walleye population. Alteration of habitat by various methods such as deforestation, sedimentation, damming, and dredging are also considered possible factors involved in the walleye decline as are water quality degradation, climatic variations, and the use of DDT.

The walleye decline in Nipigon Bay, Lake Superior, in the 1960's and its subsequent collapse was most likely due to a combination of detrimental factors. High exploitation, pollution, and habitat alteration have all affected the reproductive potential of the walleye. An understanding of the factors that led to the declining walleye population in Nipigon Bay is essential in developing a successful rehabilitation plan.

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INTRODUCTION

This historical review of the walleye population in Nipigon Bay, Lake Superior was conducted as part of the Remedial Action Plan Program initiated by the International Joint Commission in 1986. Funding for this review was provided by Environment Canada through the Great Lakes Clean-Up Fund.

From the time of the earliest settlers to present day, the fisheries of Nipigon Bay have been subjected to many influences. Even as far back as the fur trading era Nipigon Bay was utilized as a source of fish food. The intention of this report was to examine all possible factors that may have been responsible for the decline of the walleye population in the 1960's. By determining possible detrimental factors affecting historic fish populations, fisheries managers may be able to avoid similar problems in the future and to initiate rehabilitative measures.

Commercial fishing began in Nipigon Bay in the late 1800's with walleye being one of the sought after species. The total harvest of fish increased as the efficiency of fishing gear and methods became more advanced. Sport fishing also increased in popularity in more recent years.

The increased access resulting from the construction of the Canadian National Railway brought larger numbers of people many of whom utilized the fisheries resource. Fishing was conducted on a large scale in order to feed the men working on the railway. The increased population also resulted in an increased number of structures and alteration of landscape some of which affected the waterways.

The pulp and paper industry became prominent in the Nipigon area in the early 1900's. Log drives on the Nipigon River from 1923 to 1973 resulted in the accumulation of large amounts of organic debris on the bottom substrate. The Red Rock sulphite pulp mill was established in 1930 and pulp and paper making activities continue today. The amount and toxicity of the effluent released has decreased with recent awareness of its harmful effects.

Other factors are also considered in the decline of the walleye. The use of DDT as an insecticide in the Nipigon area may have had some impacts on the reproduction of walleye during that time period. The three hydro-electric generating stations on the Nipigon River may have affected the walleye populations if drawdown occurred during the critical incubation period of the eggs. It is not known if the fluctuations caused by the dams would impact the water levels on Nipigon Bay. Methods used to control the sea lamprey populations on tributaries to the Great Lakes may have affected the walleye by accidental electrocution at electrical barriers and perhaps by adverse effects of chemical control.

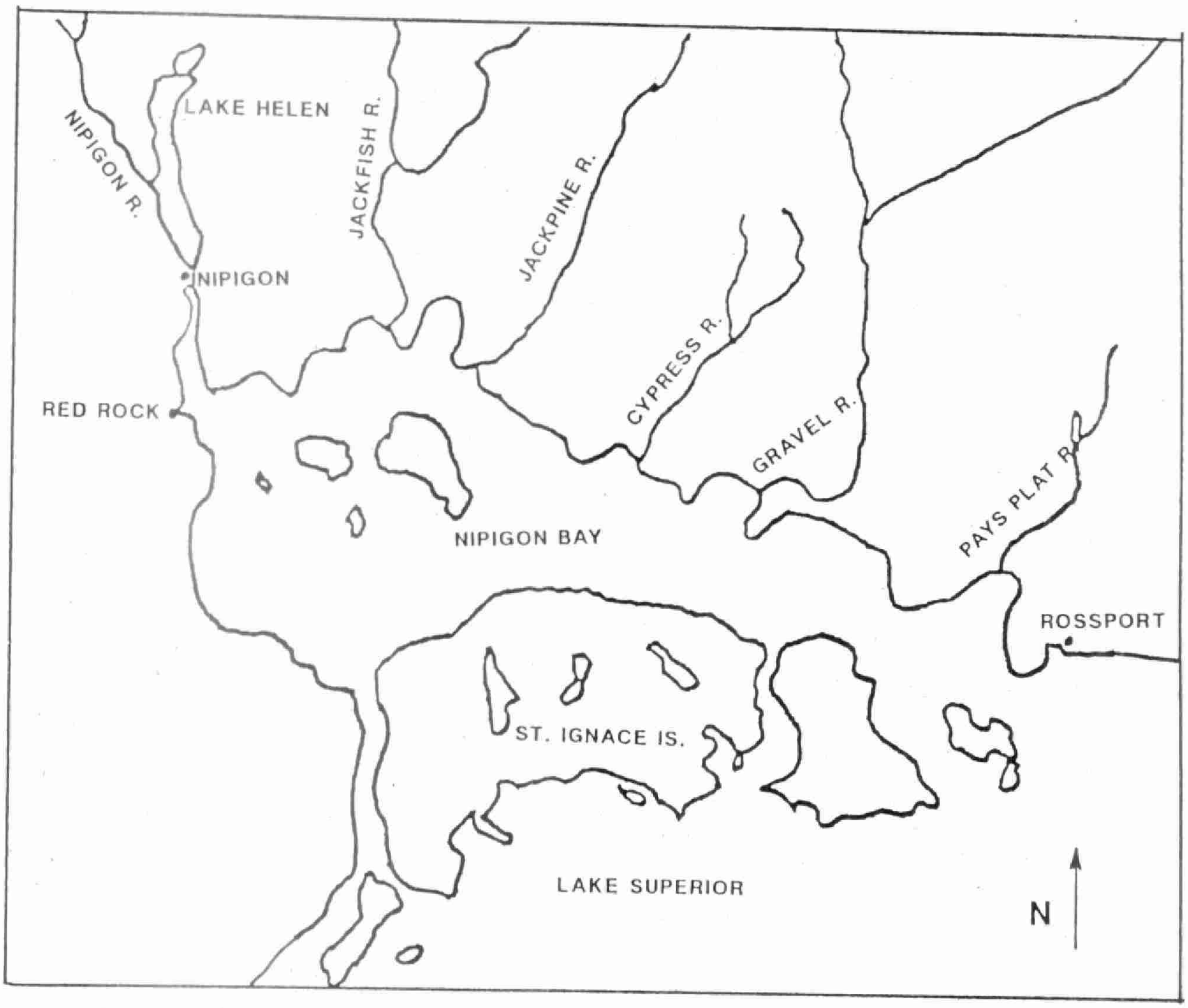


FIGURE 1. MAP SHOWING THE NIPIGON BAY AREA OF CONCERN AND MAJOR TRIBUTARIES

1. EARLY FISHERIES

During the eighteenth century, fish were traded between native fishermen and European trappers and fur traders in the Nipigon area (Figure 1). Dependence of the settlers on the local resources resulted in fish forming a staple of the daily diet. By 1839, the Hudson's Bay Company caught enough fish to be considered a commercial fishery. Seasonal outposts were maintained at the Agawa River, on Batchawana Bay, and at Red Rock. The Red Rock Post generally sought supplies of whitefish from Nipigon Bay and was further supported by a post on the northwestern shore of Lake Nipigon (Goodier, 1984). By the late 1850's the Company's commercial fishing involvement declined, but the Canadian industry flourished independently (Goodier, 1982). During this time period there was much American interest in Canadian resources including the fisheries. By 1877, the industry supported five commercial licences on Nipigon Bay and one for the St. Ignace Harbour area (Goodier, 1982). The fishery also expanded while providing a food source for those men working on the construction of the Canadian Pacific Railway during 1883 to 1885. Increased access was an important factor in the development of commercial fishing. The Nipigon Bay Fish Company, situated in Rossport, operated successfully in Nipigon Bay from 1909 until its closure in 1953. The company reportedly shipped one railway car of fresh fish, predominantly lake trout, daily by 1940 (Goodier, 1982).

For the period 1867 to 1907, official statistics for the Canadian fisheries of the Lake Superior were published in the annual reports of the federal Department of Marine and Fisheries (or Department of Fisheries). In 1907 the Department of Game and Fisheries began publishing annual catch returns. Data for the years 1871 to 1917 are recorded by station of landing to permit examination of regional fishing intensities. From 1917 to 1926 the stations were grouped into progressively larger units making comparisons difficult.

The Fisheries Act of 1857 specifically prohibited harmful practices, such as the use of certain types of nets and the destructive habit of spearing salmon by torchlight. More importantly, the Act required the Crown Lands Department to appoint, in each section of the Province, a fishing superintendent and fifteen overseers, who were to have full authority as magistrates to enforce the Statute by search and seizure (Lambert and Pross, 1962). Poaching by both Americans and Canadians was still rampant and difficult to control with the small number of overseers and government employees for such large areas. As early as 1891, these problems were coming to light.

"Overseer Keefer experienced great difficulties in obtaining reliable data for the statistical statements. Fishermen were unable to give their individual catches: this information was sought from sub-officers, buyers, shippers of fish, &c. Interested parties appear to apprehend a curtailment of their privileges or an increase of the license fees, should their catch appear too large--others, who had been fishing more nets than they were licensed for, were also unwilling to give correct returns." (Canada. Dept. of Marine and Fisheries 1891).

An example of the fishery that existed on Lake Nipigon in 1900 is illustrated below. The commercial catch, weight and value, for Lake Nepigon (sic) and Thunder Bay District for the year 1900:

Whitefish	136.2 kg	$ 24.
Trout	6901.0 kg	$ 1520.
Bass	22.7 kg	$ 4.
Pickerel	980.0 kg	$ 100.
Pike	1816.0 kg	$ 160.

Information gleaned from the annual reports of the Game and Fisheries of the Province of Ontario indicate that in 1912 there were eleven tugs operated on the Nepigon (sic) Straits to Simpson Island. The 26 men fishing this year used 59,000 yards of gillnet and 18 pound nets. Their catch was made up mainly of lake herring (249,700 kg), lake whitefish (31,388 kg), lake trout (151,908 kg), and pickerel (4,606 kg). The returns of the numbers of men fishing and their equipment from 1912 to 1918 is noted in Table 1 but caution is warranted in using the statistics as the regions covered are not consistent year after year. The returns of kinds, quantities, and the values of fish caught in the Nipigon area during this time period are noted in Table 2.

Overseer W. H. S. Gordon, of Port Arthur, reports that the fisheries of his district has been given special attention this season (Ont. Game and Fish Commission, 1911).

> One of the fishermen, who has been fishing out of Port Arthur for the past twenty years, states that this season he has had the best fishing during the past five years. It is not thought that the fishing has played out by any means, but it is believed that the fish keep moving to different grounds. The increase in the fishing has been more especially noted in connection with the pickerel. The catch of this class of fish is heavier than ever before. As there has never been any fry of this class of fish distributed in Canadian waters by the American fish hatcheries, it is, therefore, not thought that the increase of the fish is due to the fact that the fry has been set out. It is thought that the fish have increased naturally.

2. COARSE FISH REMOVAL

Many comments are noted while reviewing the Game and Fish Commission's annual reports regarding the presence of walleye in the Nipigon District. Most of the earlier reports describe the walleye as a competitor of the more prized trout and was therefore an undesirable species in the fish community.

The government-appointed overseers had a low regard for the walleye on the Nipigon River as they felt it detrimentally affected the tourist trade derived from brook trout and lake trout.

Overseer Charles de Laronde regrets to report

> "the increase of pike and pickerel on the river. These fish are making sad havoc on the trout and some camps, notably Victoria, one of the ideal pools on the river, has been abandoned by tourists, as these fish are in possession. He induced some tourists to spend part of their time capturing these fish, and very large quantities were destroyed in this way; but he thinks some more radical means should be adopted such as catching them in nets in their haunts during spawning season and destroying them" (Ont. Game & Fish Comm., 1892).

During the summer of 1901 the work of destruction of the coarse fish was entered upon, and 1800 pike, 389 pickerel, and 803 suckers were taken from the River Nepigon (sic) and destroyed (Ont. Dept. Game and Fish., 1901). In the annual report for 1902

> "Overseer McKirdy is pleased to report that the war waged against the pike (which were fast taking control of certain portions of the river) has been a decided success. Some thousands of pike which would average 10 lbs. each have been destroyed, as well as large numbers of pickerel (equally destructive to the trout) and suckers. He suggests continued netting of these destructive fish (Ont. Dept. Game and Fish., 1902).

The following note is taken from the 7th annual report of the Ontario Department of Game and Fisheries. Doré refers to walleye.

> "In 1905, one man was employed for a period of six weeks, during the months of July and August, netting these coarse fish, during which time he destroyed 7,632 pike, 2,282 suckers, 228 doré and 145 white fish making a total of 10,287 fish destroyed by this means."

The effects of this removal program did not seem noticable. The overseers complained about the coarse fish until they miraculously discovered the marketability. The walleye was of course utilized in other areas at this time but it seems to have been overshadowed by the famous brook trout of the Nipigon River.

Table 1. Return of kinds, quantities and values of fish caught in the Nipigon area.*

Year	Region	Herring salted (brls)	Herring fresh (lbs)	Whitefish fresh (lbs)	Trout salted	Trout fresh	Pike (lbs)	Pickerel (Dore)	Sturgeon	Tullibee	Mixed and Coarse Fish	Value ($)
1912	Nipigon Straits to Simpson Island		550000	69137		334600	3130	10145	1700			69393
1913	Thunder Cape to Simpson Island		1000	45191	600	121571	4230	16800	3000		3395	
1914	Nepigon Bay and Straits Dog Lake, Swede Island, Sturgeon Bay, Moffat's Straits		146000	27405		137000	2200	200				13491
1916	Pays Plat, Gravel Bay, Shesheeb Bay, Nepigon Bay		200000	4350		49815	50	8000		145		16229
1917	Kama Station, Point Edward, Moffat's Straits	204	61000	17655	4	72425	20	10490	25			15252
1918	Port Arthur, Point Magnet, Fort William, Nipigon Bay	37000	727497	40695	6100	142640	31	1925		5785		59560

* Source: Annual Reports of the Game and Fish Commission of the Province of Ontario.

Table 2. Return of the number of fishermen, tonnage and value of tugs, vessels and boats, the quantity and value of all fishing materials employed in the fishing industry for the Nipigon area.*

Year	Region	Tugs and Vessels				Boats			Gillnets		Pound Nets	
		#	Tonnage	Value	Men	#	Value	Men	Yards	Value	#	Value
1912	Nepigon Straits to Simpson Island	11	110	12175	26	3	90	3	59000	1810	18	2900
1913	Thunder Bay to Simpson Island	4	115	15200	16	2	135	4	49000	3400	4	500
1914	Nepigon Bay & Straits Dog L., Swede I., Sturgeon Bay, Moffat's Straits	3	26	2900	9	6	420	10	121500	2680	11	2030
1916	Pays Plat, Gravel Sheesheeb & Nepigon Bays	1	20	1500	4	4	245	5	16300	1130	5	800
1917	Kama Station, Point Edward, Moffat Strait	1	10	1000	3	2	125	2	18000	1300	7	1100
1918	Port Arthur, Point Magnet, Fort William, Nipigon Bay	3	63	8700	36	3	575	4	132600	8240		

* Source: Annual Reports of the Game and Fish Commission of the Province of Ontario.

Table 3. Distribution of walleye catch (in pounds) by month for both gill- and poundnets in Nipigon Bay, 1954-65.*

Year	Jan. - Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1954	169	3225	7453	5821	16	91	185	472	60
1955	2	449	2626	588	5195	3618	413	485	
1956		87	18	249		1367	2040	885	
1957		90	23096	5655		85	16	6	
1958	159	5992	23692	3695		1095	541	62	
1959		7463	8137	214					
1960		1467	6461	318					
1961		2060	5134	253					30
1962	1830	1584	2127				18		
1963		654	2931				5	141	
1964		460	2578	313			447	73	
1965		198	2191			59		11	
Total	2160	23729	86444	17106	5668	6315	4029	2135	90
Mean	540	1977	7204	1901	1889	1052	504	267	45

* Source: Ryder, 1968.

3. COMMERCIAL FISHING

As the commercial fishing industry became more efficient, the harvests increased. The introduction of nylon into gillnets appeared between 1948 and 1953 resulting in stronger and more versatile nets. The new nets were more efficient than the earlier cotton or linen by a factor of 2 or 3. This increased efficiency was further magnified by increased handling efficiency, since artificial fibres did not need to be dried and did not become fouled by aquatic organisms (Regier and Hartman, 1973). The end result is the same amount of effort expended to harvest a considerably larger catch. Data on effort alone is not acceptable as a means of monitoring the strength of the population. In 1948, the CF-1 form was implemented for the recording of detailed information on the commercial fishing at individual stations.

Schneider and Leach (1977) note that the walleye populations of Lake Superior have always been relatively small and widely scattered, primarily because the amount of shallow, warm water habitat is limited. The highest annual lake-wide catch from 1800 to 1975 was only 171 tons in 1966. Walleyes taken from Ontario waters were harvested principally from Black Bay, and to a lesser extent, Nipigon Bay. The commercial catch of walleye (1918-1978) from landings on the Canadian side of Lake Superior is noted in Figure 2.

3.1 COMMERCIAL FISHERY OF NIPIGON BAY

The commercial fishing industry harvested considerable amounts of lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), and walleye (*Stizostedion vitreum vitreum*) in Nipigon Bay prior to 1950. The walleye fishery did not make up a significant portion of the catch until the catches of lake trout and lake whitefish began to decline in the late 1950's. In 1957 and 1958, walleye harvest, although not greater than in 1947 and 1951, nevertheless contributed a substantial proportion of the total catch (Ryder, 1968). The walleye population in Nipigon Bay ranked second in importance in Ontario waters of Lake Superior, contributing 6% of the commercial harvest in 1948-75 (Schneider and Leach, 1977). Black Bay was ranked first in importance. The decline of the lake trout resulted in a shift in fishing effort towards walleye. The spawning aggregations of walleye were easily found, particularly in May and June, by the commercial fishermen and were heavily exploited (Table 3). Ryder (1968) estimated that the annual mortality rate from fishing increased from 0.10 in 1955 to 0.39 in 1957. However, he believed that exploitation was not a major factor in the decline of walleye because ice conditions precluded fishing during the upstream migration, and most walleye were caught in Nipigon Bay after the spawning season. Local fishermen (Dampier, pers. comm.) also stated that the walleye had completed spawning and were migrating back down when they were captured in the commercial nets.

Walleye were commercially harvested in the northwestern portion of Nipigon Bay at an average yearly rate of 8,813 kg from 1954 to 1959 (Ryder, 1968). Annual yield was variable in 1948-58, ranging from 2 to 16 tons (Figure 20)(Schneider and Leach, 1977). From a peak in 1958, the commercial harvest in Nipigon Bay declined to nil in 1966 and did not recover (Figure 3). Similar trends are noted in Lake Superior with the commercial catch of walleye peaking in 1967 and declining drastically following that period (Figure 2). Adult walleye remained in Nipigon Bay for several years after spawning ceased, but were gradually lost to natural mortality and to the commercial fishery. The population did not drop off quickly as it did in Black Bay but rather tailed off to low levels with a few large walleye still present (Ryder, pers. comm.). Ray Dupuis (pers. comm.) also noted that during the last few years before the disappearance of the walleye, the fish seen on the spawning site below the Nipigon River highway bridge were large with few small individuals noted. No walleye were caught during a 1974 study of the fishes of the Red Rock area (Kelso et al., 1977).

The catches of walleye by the commercial fisheries in Nipigon Bay remained almost negligible (average of 11 kg per year) from 1973 up to the closure in 1984 as illustrated by production comparisons in Table 4 (Nipigon District Fish and Wildlife Annual Reports). In 1973, only 100 kg of walleye were caught with an approximate value of $153.30. The commercial harvests from the two commercial licences in western Nipigon Bay from 1953 to 1973 illustrate the declining walleye population (Figure 4). The major community change noted in the commercial statistics was the 4500% increase in the perch production for 1974. This accounted for the overall increase in production and monies. In 1978, Nipigon Bay was designated as Fishing Zone 3 (Figure 5) for which two licences were issued for the Nipigon Bay portion this year. Each fishermen was allocated a lake trout quota of 2240 lbs. (1016 kg) of lake trout and an experimental licence for herring of 4480 lbs. (2034 kg). The walleye production in Zone 3 was limited from 1976 to 1979 with the amount of walleye caught weighing a total of 209 lbs. (95 kg). The perch production reached a peak of 10,136 kg in 1977 (Vander Wal et al., 1989) but only remained significant until 1982.

3.2 COMMERCIAL FISHERY REGULATIONS

The Nipigon Bay area closure to commercial fishing until June 30th each year began in 1980 with the intent of protecting an angling fishery for perch. Restrictions prior to 1980 dealt mainly with quotas regulating the amount of fish harvested (Table 5). Animosity existed between the commercial fishermen and the anglers in Nipigon Bay until this closure was put into effect (Dupuis, pers. comm.). Angler objections to the presence of the commercial fishermen had accelerated as a result of the apparent drop in perch fishing success since the mid-1970's.

Table 4. Nipigon Bay (Zone 3) commercial catch production in pounds, 1976 to 1983.*

Species	1976	1977	1978	1979	1980	1981	1982	1983
Chub	0	0	1106	8852	5321	1592	0	0
Herring	0	0	212	98	15	1578	65	0
Lake Trout	956	518	1099	1292	641	451	12	919
Northern Pike	116	296	149	16	41	61	36	10
Perch	7246	22832	16890	9570	482	3296	1444	138
Menominee	0	0	0	186	0	0	0	0
Mullet	8448	4346	12068	13813	3766	9323	8573	3238
Whitefish	13619	10962	11118	4397	10636	17788	16966	19327
Walleye	25	85	62	37	0	18	18	2
Total	30400	39039	42704	38261	20902	34107	27114	23634

* Source: Nipigon District Annual Fish and Wildlife Reports

Table 5. Organization of commercial fishing on Nipigon Bay.

late 1800's to 1947	- catch locations were not site specific and the commercial industry was largely unregulated - a modified block system where individual fishermen had exclusive rights to a block was used - the block was sold with the fishing licence
1948	- CF-1's implemented vastly improving commercial harvest statistics
1962	- zone quotas for lake trout established on Lake Superior - these consisted of a spring quota taken from May 5 to September 9 and a fall quota taken from September 10 to November 30 (unless the total quota had been taken in the spring term)
mid 1970's	- zone quotas established for all other major commercial species
1976	- western Lake Superior was broken up into new fishing zones - specific lake trout quotas were assigned - Zone 3 - Nipigon Bay Zone 4A - outer St. Ignace Island area Zone 4B - Bateau Rocks area, offshore area
1981	- whitefish, herring and yellow perch quotas were established
1984	- "modernization of Ontario's Commercial Fishery" - reorganization of quota zones into Fisheries Management Zones - Zone 3 became F.M.Z. 10 and 11 - individual quota management for all species in each zone - allocation of "individual" quotas to fishers licensed for each zone after zone quotas were established
1985	- first complete year under the new management plan - commercial fishing terminated in the western portion of Nipigon Bay with the two licences being purchased by the Ministry of Natural Resources

The decline in the number of perch in Nipigon Bay is also evident in the commercial production (Table 4). The commercial fishermen were previously allowed to net during spawning season while the season remained closed to the anglers (Dupuis, pers. comm.).

After three years of discussion with the industry, individual whitefish quotas were made a condition of the Lake Superior licences in 1981. A whitefish quota of 47,000 lbs. (21,338 kg) was agreed upon for Fisheries Management Zone 10 (Figure 6). The zone quota for perch was also established.

In 1983, the lake trout quotas were filled by all fishermen on western Lake Superior except those on Nipigon Bay. Lake trout stocks have not rebounded in Zone 10. At this time Nipigon Bay was classified as both Quota Zone 3 and Management Zone 10. The annual lake whitefish commercial harvest increased during the early 1980's. This may be a result of the more fecund whitefish responding more quickly to the decline of the sea lamprey (Vander Wal et al., 1989). Two cases of a one time increase in whitefish quotas were granted to two commercial fishermen of Nipigon (Zone 3). This decision was based on the apparently healthy state (mean age of catch greater than 6 years) of the populations in the eastern end of Nipigon Bay (Cullis, 1983). Perch were not actively sought by the commercial fishermen because of the high incidental catch of immature lake whitefish in the nets.

In 1984, the Zone 10 quota for whitefish was surpassed and an additional 807 kg of whitefish was granted as a result of increased CUE's and an apparently stable population structure (Cullis, 1984). The only significant commercial catch in Nipigon Bay in 1984 was that of lake whitefish.

Buyouts of commercial fish licences in the western portion of Nipigon Bay in 1985 by the Ontario Ministry of Natural Resources removed commercial interests from these waters (Fisheries Management Zone 10). Habitat reclamation and rehabilitation of walleye, lake trout, and brook trout is currently underway.

3.3 COMMERCIAL FISHERY OF BLACK BAY

The walleye decline of Black Bay will also be discussed in this section as the collapse of this fishery followed that in Nipigon Bay. The commercial yields from Black Bay contributed 84% to the total harvest taken from the Ontario waters of Lake Superior between 1948 and 1975 (Schneider and Leach, 1977). In comparison with Nipigon Bay, Black Bay is much shallower and more turbid, therefore, more conducive to walleye. Ryder (pers. comm.) notes the water quality in Nipigon Bay as being austere with few areas suitable for walleye.

The walleye in Nipigon Bay were river spawners while those in Black Bay were able to spawn on several different locations including shoals in the bay and the Black Sturgeon River. The commercial harvest appeared to be fairly stable from 1910 to 1950 and then increased in the 1950's and the 1960's. After a peak yield of 170 000 kg in 1966, the harvest dropped rapidly to 123 000, 52 000, and 9 000 kg in successive years and finally to nil in 1972 (Schneider and Leach, 1977; MacCallum and Selgeby, 1987)(Figure 20). No contributing causes to the walleye decline were found when an examination of water quality was conducted by field personnel of the Ontario Ministry of Natural Resources (Schneider and Leach, 1977). Ryder (pers. comm.) believed that overexploitation led to the demise of the Black Bay population. Fishing effort increased in the mid-1960's, causing changes in the year-class structure in the commercial fishery. Some of the increased pressure may have been redirected from the fishermen that previously fished on Nipigon Bay. The Black Bay walleye population was reduced to two year classes by the extensive exploitation, although these constituted some of the largest catches (Ryder, pers. comm.). The population collapsed dramatically with the harvest of these two year classes. It appears that year-class success was poor in the middle and late 1960's and, in the absence of adequate recruitment, the Black Bay stock was quickly removed by the fishery (Schneider and Leach, 1977). Colby and Nepzy (1981) attributed the decline of the Black Bay walleye stock to overfishing.

Figure 2. The commercial catch of walleye from landings on the Canadian side of Lake Superior, 1918 to 1978.
Source: Baldwin et al., 1979.

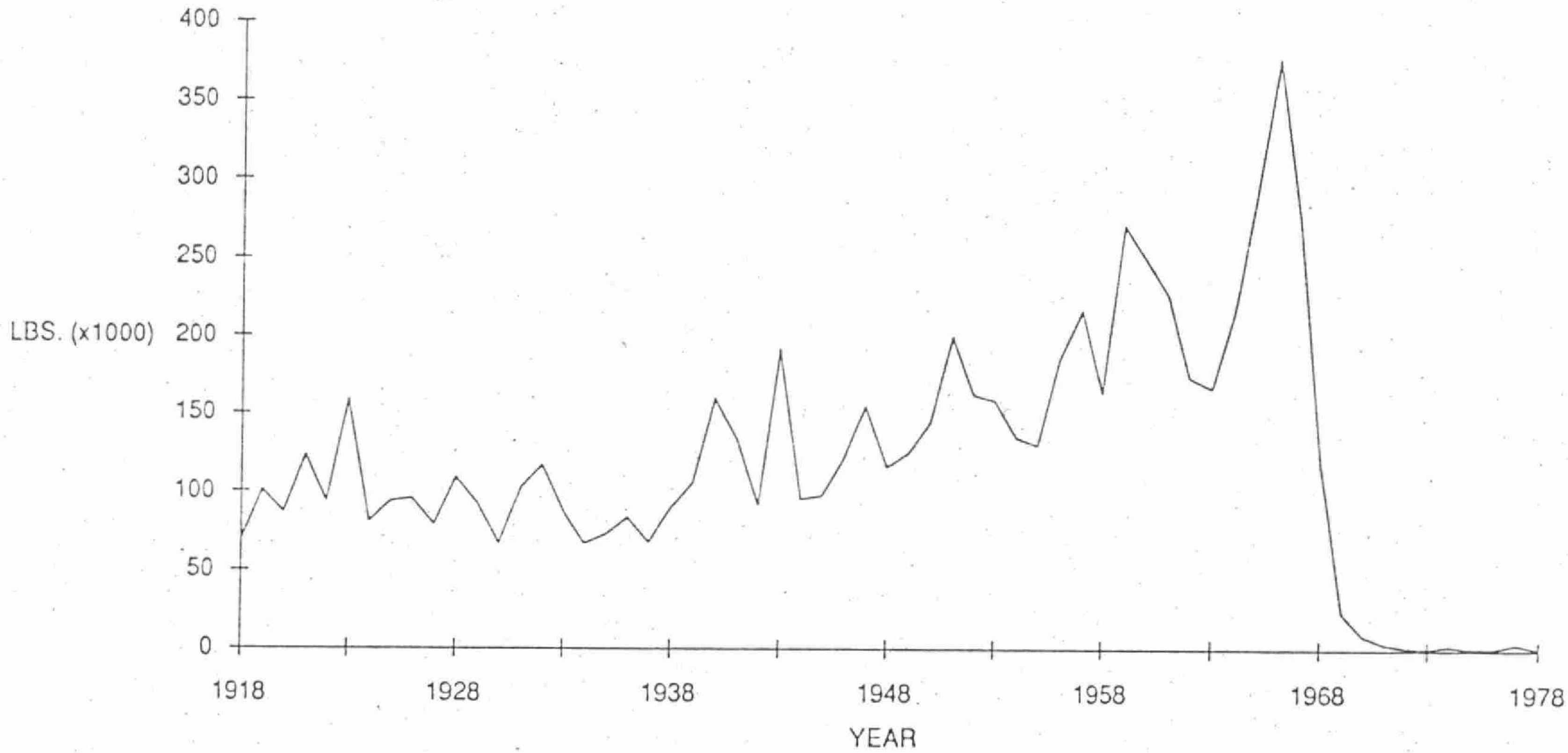


Figure 3. Summary of commercial catch data for the walleye fishery on Nipigon Bay, 1954-65.

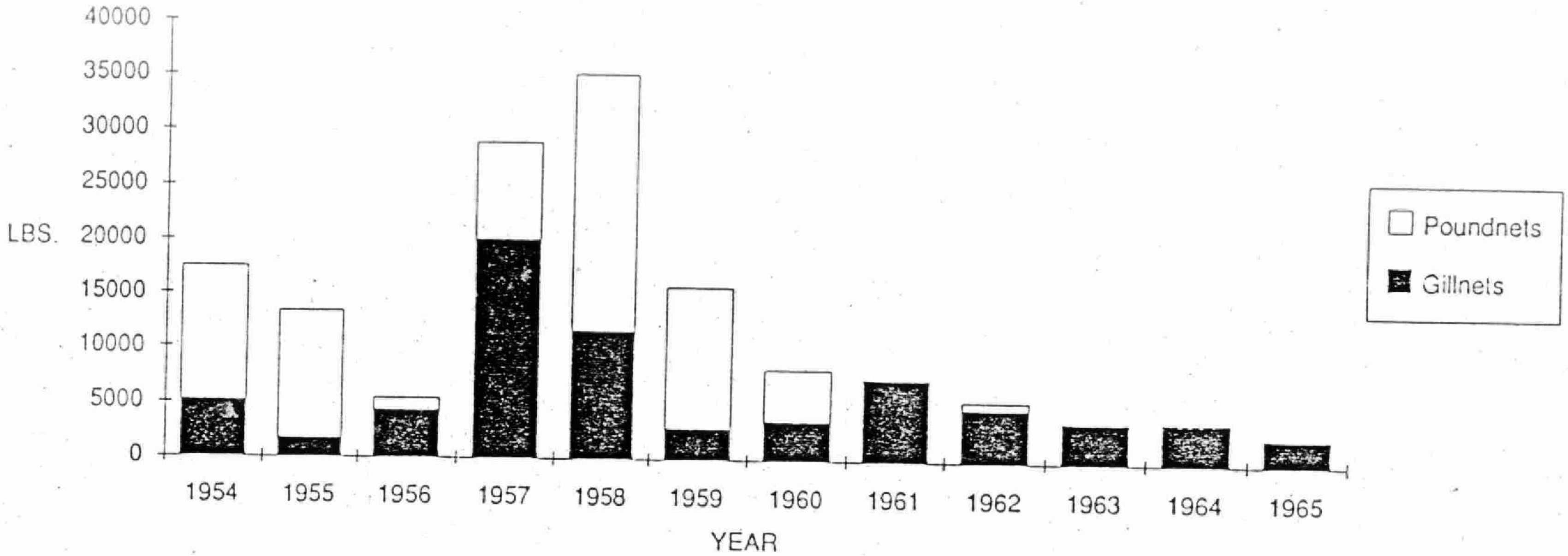
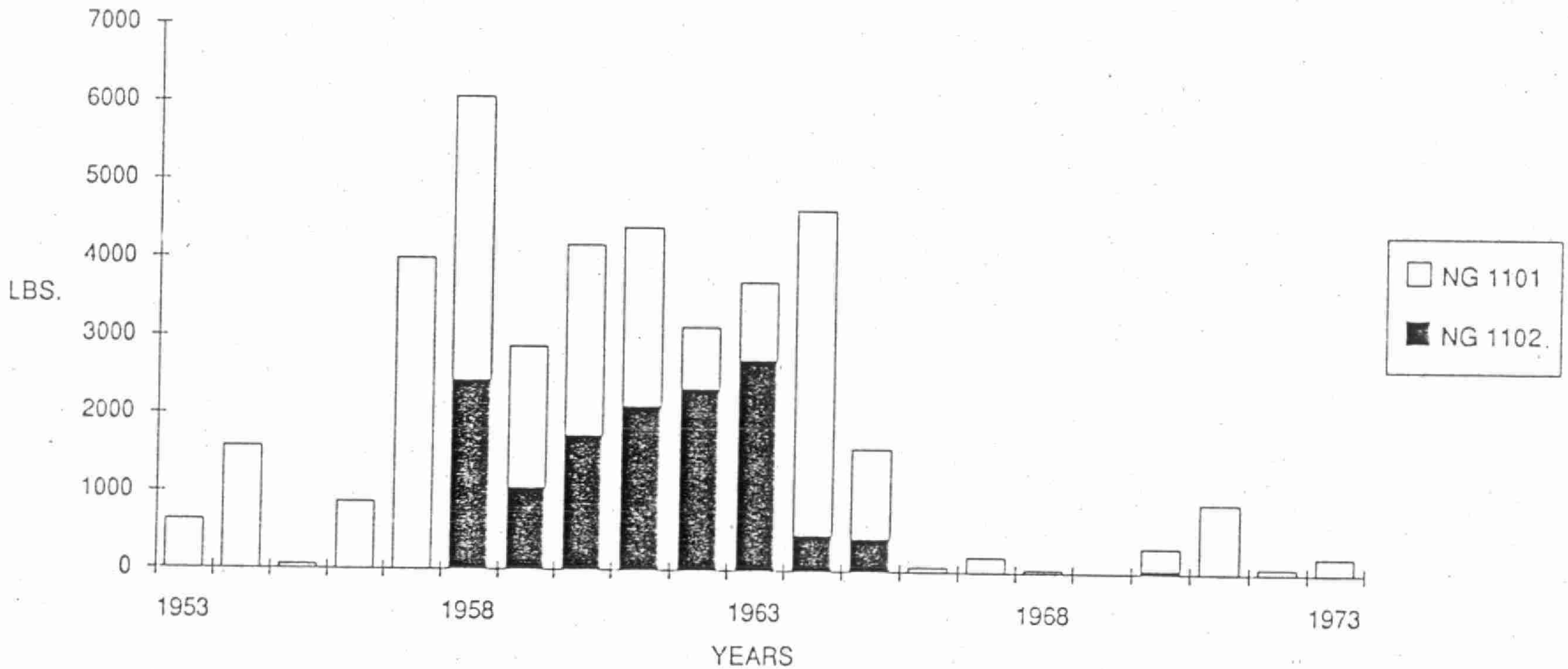


Figure 4. The commercial harvest of walleye of two commercial licences in Nipigon Bay from 1953 to 1973.



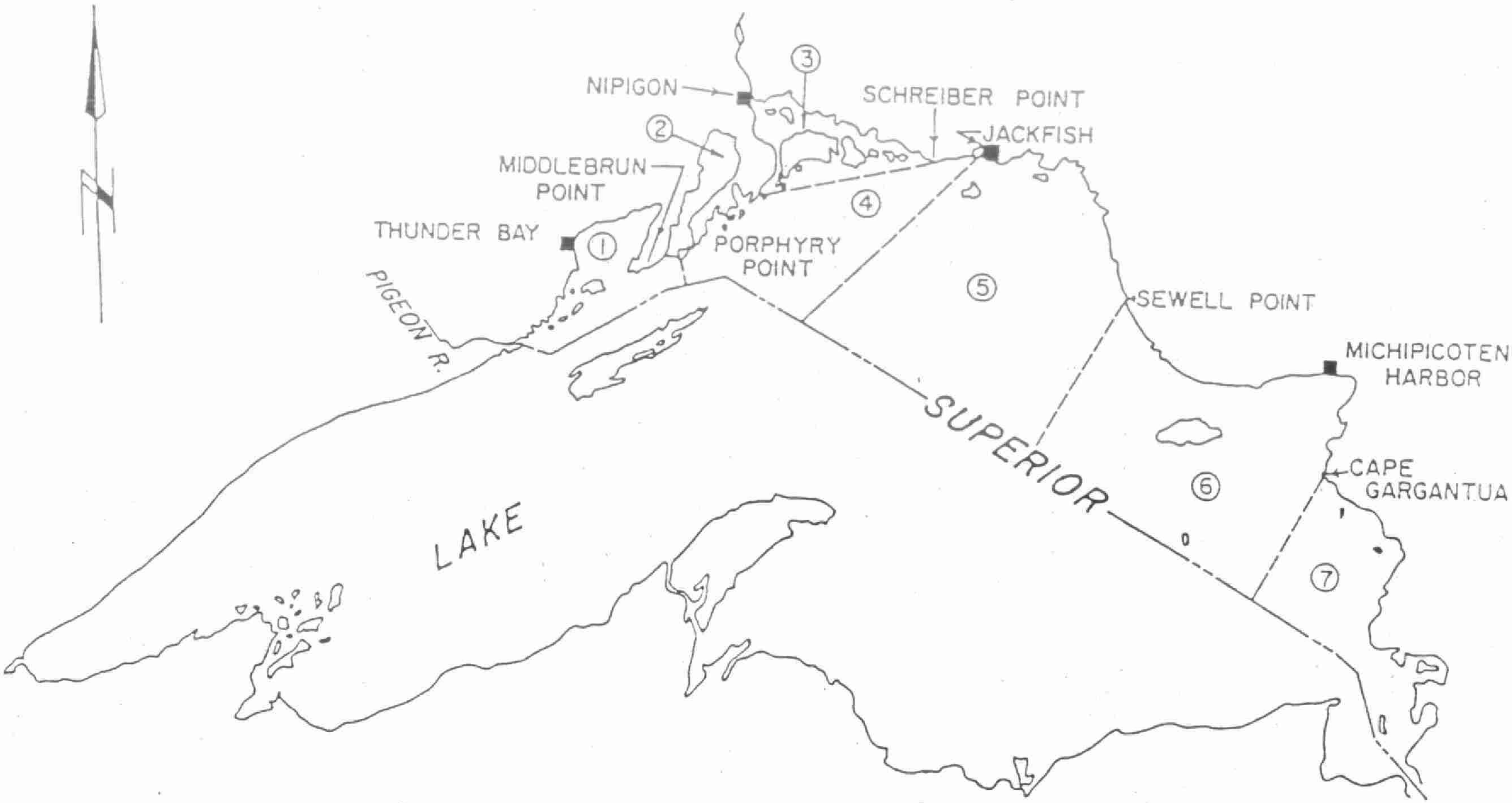


FIGURE 5. FISHERIES STATISTICAL DISTRICTS OF LAKE SUPERIOR

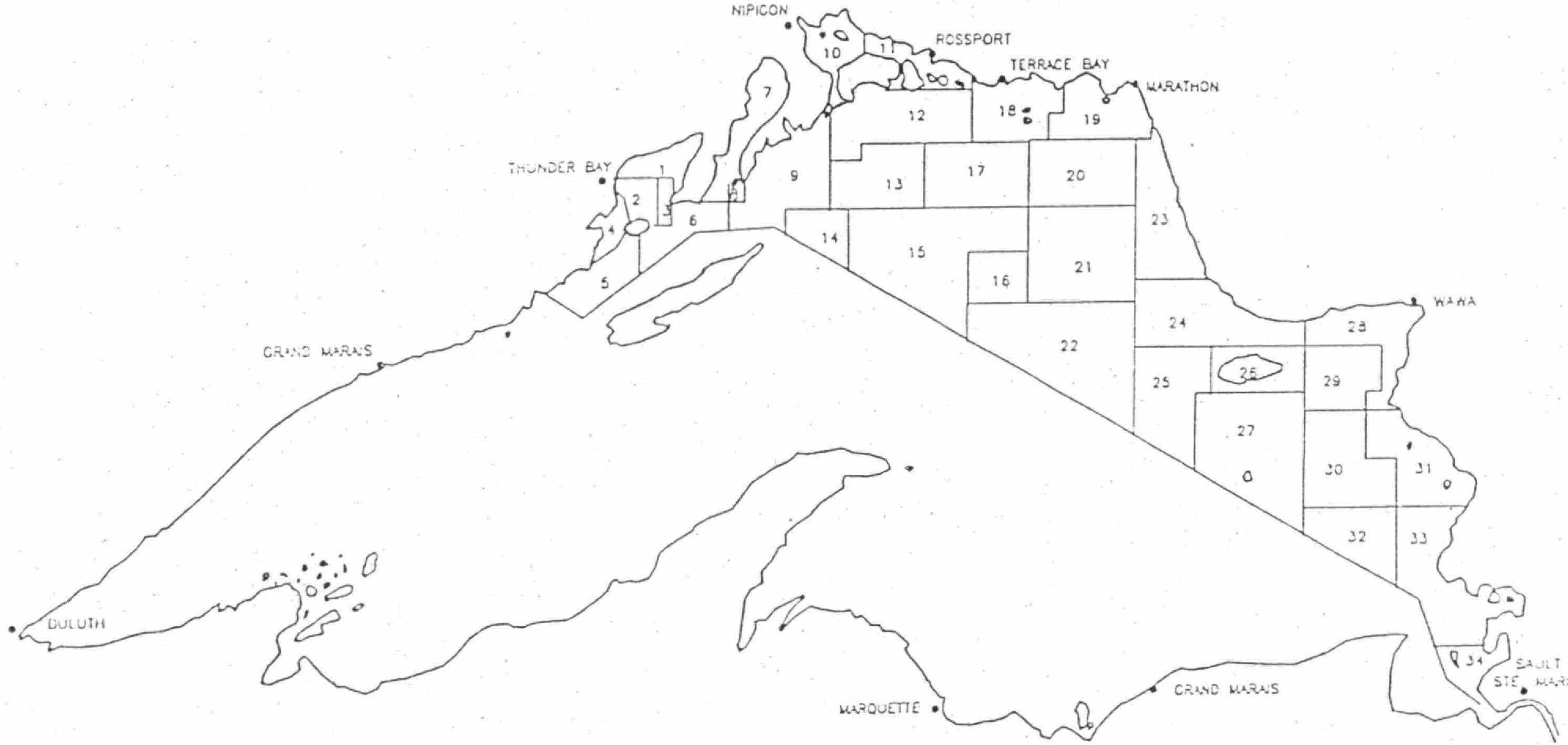


Figure6 : Lake Superior Fisheries Management Zones.

4. SPORT FISHING

The majority of the sport fishing in the late 1800's and early 1900's was concentrated on the brook trout in the coldwater streams of the Nipigon area. Walleye were not even considered as a game fish during this period. To the contrary, walleye were considered a coarse fish by the anglers as well as by the fishery overseers.

This note is taken from a diary written in 1877 while the author is engaged in a trout fishing trip on St. Ignace Island in Nipigon Bay:

> " The larger island contains in itself numerous small lakes which abound in pike, and what we Canadians call yellow pickerel, really pike-perch. No one bothers catching these however as the surrounding waters yield an enormous supply of choicer fish among which are said to be, ten varieties of the salmon family; besides the whitefish, among which are said to be seventeen pounds in weight!" (Thomson, 1877).

These notes were taken from E.E. Millard during a brook trout fishing trip on the Nepigon (sic):

> "Adjoining the camping grounds below Virgin Falls on the east side, just off the rapid current, is a favorite lurking place of the pike and pike-perch (walleye). During most seasons they are plentiful enough, though the angler who procures a license for fishing the Nepigon squanders little time with them, for they are not worth the powder, and it would be like casting pearls before swine." (Millard, 1917).

> "The pike-perch (walleye), another denizen of these waters, and more commonly known as the wall-eyed pike, possesses many characteristics of the pike, though being a great improvement on him and quite a king by comparison. He ought to be a cousin, a second cousin or at least a collateral relative, though properly belonging to the perch family. He also is rarely caught in the swish and roar of the white caps, much preferring the weeds; and having no commendable fighting qualities, he quickly displays the yellow streak and is easily landed." (Millard, 1917).

> "He may be fairly palatable on the table when properly served and cautioned to be on his good behavior, but makes no special appeal to the sportsman angler, though apparently satisfying the requirements of the professor of the hand-over-hand line, the deadly gang-hook and other mechanical monstrosities and contraptions." (Millard, 1917).

Regulations taken from the Ontario Game and Fish Commission (1892) regarding the walleye consisted of a closed season from 15th April to 15th May. Other regulations of interest were the licencing of trout anglers:

- persons who do not reside in the Province must procure from the Commissioner of Crown Lands a permit or licence before beginning to fish
- the fee is $5 and the permit shall be good till the end of the angling season of the year for which it is granted

In 1904, amends were made to the Fisheries Act of 1889 for the Province of Ontario as follows:

- no one shall fish for, catch, or kill in any of the waters of the Province, in one day by angling, or shall carry away a greater number than 12 pickerel (Doré) or four lake trout
- no pickerel less than 15" in length may be kept

Sport fishing in Nipigon Bay was limited prior to 1950 due to the lack of boats in the area and perhaps due to the lack of leisure time. There is evidence of a considerable sport fishery for brook trout but it was limited mainly to the Nipigon River. In Lake Superior, sport fishing declined drastically during the 1960's and remained insignificant until the lake trout fishery and especially the Pacific salmon fishery became important (MacCallum and Selgeby, 1987). Local residents feel that the sport fishing industry did not become prominent on the Bay until the late 1950's. At this time a substantial walleye sport fishery existed in Polly Lake and the Jackfish and Nipigon River areas. Angling in Nipigon Bay proper normally did not occur with walleye being taken incidental to lake trout (Walroth, 1980). Approximately 28% of total tag returns from 2,200 Nipigon Bay walleye tagged between 1955 and 1958 were recovered by sport fishermen (Ryder, 1968). The angler concentration is indicated by the fact that 80% of the tags returned from the sport fishery were taken from Polly Lake and almost all the remaining 20% were taken in the Jackfish and Nipigon Rivers. Local residents note without fail the tremendous walleye fishing under the log boom storage areas in the southern portion of Lake Helen and at the mouth of the river. Jiggs McInnes (pers. comm.) remembers when ten casts below the bow boom under the highway bridge would bring, without a doubt, at least nine walleye. Bob Matchett (pers. comm.) has been a trailer park owner on Lake Helen since 1964 and participant in the log drives from 1945 up until they ended in 1973. He notes that in the late 1940's and 1950's the walleye were so plentiful that one could scoop them up with a dip net in the rivers and subsequently much poaching took place. Prior to 1961, he notes that fishing on Lake Helen was strictly for walleye. Fifty or sixty local people could be fishing from the booms in front of his property at one time and all would get their limit of six walleye (1940's and 1950's). Matchett also noted that the Lands and Forest people charged 15 people with poaching for walleye during this time period.

Dupuis (pers. comm.), an avid sport fisherman in the local area, feels that the walleye population began to decline in 1965. Prior to this time, there were many locations where a limit of walleye could easily be caught. In the mid-1950's, Dupuis notes that not only would people angle for the walleye but they would also engage in spearing and snaring prior to the opening of the season while the walleye were still spawning below the highway bridge.

During a creel census conducted on Polly Lake in 1957 it was determined that 1508 kg of walleye were removed by sport fishermen (Ryder, 1968). The angling took place from the opening of the season (May 15 in 1957) to the end of August (Table 6B) Fishing is extremely poor by early September and angling occurs only rarely in the fall and winter (Ryder, 1968). Ryder also notes that angling specifically for walleye does not occur on Nipigon Bay therefore the Polly Lake creel would account for a large percentage of the sport fishing. Creel censuses were conducted on the lower river in 1987 and in 1988 (Table 6A).

Prior to the walleye decline in the 1960's, there existed a gentlemen's agreement between the anglers and the fishermen that no nets would be set north of Vert Island, from approximately the Jackpine River to Five Mile Point. After the walleye populations collapsed, angling decreased and the traditional agreement was forgotten. In 1980, pressure was placed on the Ministry by local angling associations resulting in the closure of an area around Hughes Point until June 30th of each year (Goodier, 1981). This closure was enforced mainly to protect the perch fishery.

A sport fishing review was conducted in 1986 to assess the impact of angling on the fisheries of Lake Superior. At this time the waters of Lake Superior were open to angling all year. Walleye populations throughout Canadian Lake Superior were badly depleted or extinct and several major walleye rehabilitation initiatives were underway. The Nipigon River was one of the tributaries that the working group considered as requiring immediate protection for existing walleye stocks and for the protection of future stocks. A closed season from April 15th to June 30th was recommended for Lake Superior proper. A closed season from April 15th to the third Friday in May was recommended for walleye and sauger in Nipigon Bay. Another recommendation involved the reduction in the limit of walleye from 6 to 3 on the Lake Superior shoreline and on the lower reaches of the Nipigon River but it never took place. A 1987 co-operative angler creel program revealed that few anglers fished in Zone 10 compared to adjacent zones, and the target species was predominantly chinook salmon rather than lake trout (MacCallum, 1988).

In 1989, the Nipigon Bay, the Nipigon River and the Jackfish River were closed to walleye angling year round to assist rehabilitation efforts.

Table 6A. Creel Survey summary: lower Nipigon River, Sept. 1 - Nov.1, 1987 and July 21 - Nov. 1, 1988.

Species	Effort (hours)	Estimated Harvest (numbers of fish)	CPUE 1988	CPUE 1987
Walleye	32	5	0.154	0.01
Coho Salmon	117	10	0.084	
Chinook Salmon	1779	173	0.094	0.00
Rainbow Trout	3731	552	0.146	0.06
Brook Trout	2024	135	0.051	0.03
Lake Trout	224	133	0.355	
Lake Whitefish	86	170	1.762	
Pink Salmon				0.03

* The data for 1987 consists only of the CPUE
The lower values for 1987 correspond with a short period of creel

Source: Nipigon District files

Table 6B. Creel Survey summary: Polly Lake, May 15 to August 31, 1957.

Month	Effort (hours)	Estimated Harvest (numbers of fish)	CPUE
May	224	43	0.19
June	1502	441	0.29
July	1261	354	0.28
August	1549	679	0.44
Total	4536	1517	0.33

Source: Ryder, 1968.

5. ALTERATION OF HABITAT

5.1 DEFORESTATION

Removal of the forest cover beginning in the 1850's, may have favoured the walleye by warming the relatively cold spawning streams or stimulating productivity; conversely, reforestation during the past 50 years may have had a negative effect on walleye recruitment by cooling streams or reducing inflowing nutrients (Schneider and Leach, 1977).

Prior to the 1900's little mention is made of walleye in the fisheries records, due either to low abundance or lack of reporting. The presence of walleye is noted as a coarse fish in the early 1900's but only briefly by comparison with the much more popular brook trout. Coincidentally, the decline of the coldwater fish species such as brook trout occurred at the same time as the increase in the warmwater walleye. Changes may have favoured walleye habitat while becoming less suitable for trout.

Deforestation increases surface runoff adding warmer water to the cool streams. Deforestation would also contribute increased amounts of organic debris and sediment to the water systems. Increased turbidity also favours walleye and is avoided by the trout. As the trees have grown and the practice of silviculture developed, the streams and rivers have become clearer and runoff is less resulting in little temperature change. The time frame of these activities seems to correspond generally with the rise and fall of the walleye population in Nipigon Bay. Deforestation may be a minor factor acting in conjunction with others.

5.2 LOGGING

> At Nepigon (sic), however, a danger is felt for the trout fishing. Recently the Government has advertised timber berths for sale on Nepigon (sic) Lake, and it is feared that the purchasers of the timber might endeavor to bring all the timber to Lake Superior via the Nepigon (sic) River. This would destroy the stream as a trout stream, and it is thought that every effort should be made to keep this stream in its present natural state. In view of the fact that hundreds of visitors from outside points come to this district every summer to fish in the Nepigon (sic), the stream is now looked upon as a national stream, and it is felt that it would be a crime indeed to spoil this stream by the running of logs and pulp wood down the river (Ont. Dept. Game and Fish., 1911).

Log drives were conducted on the Nipigon River from 1923 to 1973. Logs were stored above Virgin Falls before each drive, then were run over the falls then run over the falls at Pine Portage. Logs were then stored between Split Rock and the narrows above Jessie Lake. Logs were towed by tug down Lake Jessie to Cameron's

Pool, above the falls (today Cameron Generating Station) where they were stored again. From there logs were run to Lake Helen where they were stored until they could be towed to a mill on Lake Superior (Figure 8). It is estimated that less than two percent of the wood run down the river remained in the Nipigon system and that the total annual volume of the drives ranged from 200,000 to 400,000 cords with 485,000 cords being the most ever run in a year.

The early 1950's saw a number of pulp and paper companies boom a total 400,000 cords per year down the Nipigon River system. In the 1960's, the two major companies (Domtar and Abitibi) were booming 275,000 cords per year. In 1971, these two companies reduced their log drives to 200,000 cords . Log drives were completely phased out by 1973.

Short term effects of the log drives

Increases in water level that accompanied the running of logs through the chutes at the dams may have proved detrimental to the fisheries of the river system. According to Matchett (pers. comm.) the timber companies could request an increase in flow from Hydro if it was needed to move the log booms more smoothly. The presence of large amounts of logs on the river had an impact on the fisheries. According to local fishermen, the storage areas for the logs provided cover and a food rich environment for fish - several individuals mention large may-fly hatches emerging from under the log booms and the concentrations of fish that they attracted. Others believed that the walleye, being negatively phototaxic, enjoyed the shade offered by the log booms. Bark and woody debris may have accumulated in the short term but has since been removed by flushing of the river system. In rapidly flowing stream sections, fish eggs deposited on and attached to the bottom would be exposed to abrasion by suspended fiber particles. Mechanical action of suspended wood fibers at concentrations as high as 250 ppm had no measurable effect upon the survival of walleye eggs (Kramer and Smith, 1966)

Long term effects

Destruction of spawning habitat may have occurred by the scouring action of the logs as they were swept down-river. Accumulation of large amounts of allochthonous material and woody debris may have reduced the amount of suitable spawning habitat by covering the gravel beds that were normally used. Matchett (pers. comm.) notes that bark is still washed up on the shores of Lake Helen in considerable quantities during a storm. Areas in the river do not seem to be as affected due to the greater flow, although backwaters and eddies have accumulated bark and the area in the immediate vicinity of the Red Rock mill has some accumulation of debris (Dupuis, pers. comm.). Decomposition of the woody material could result in reduced oxygen.

A field investigation of the Nipigon River was conducted in 1982 by Pat Furlong of the Ontario Ministry of Natural Resources to determine the feasibility and consequences of salvaging sunken logs on the Nipigon River downstream of the highway bridge (Nipigon District files). Furlong (1982) suggested that the sunken log piles may be responsible for the deposition of material and hence the loss of fish spawning habitat. Removal of the logs would re-establish the natural flow regime on the west bank of the Nipigon River. Potential benefits of log removal include flushing and cleansing of spawning areas and altered flow patterns. Exposure of rock substrate will also increase production of aquatic invertebrates, a potential food source.

5.3 SEDIMENTATION

During particulate analysis, Leslie (1977) noted that wood fiber discharged at Red Rock mill rapidly dispersed and settled once outside of the immediate discharge area, but was still evident at points approximately 2 km distant. The presence of bark and/or wood chips was found in the top 10 cm of most of the samples within 6 km of the mill outfall and organic fibers were visible in all bottom samples within 1.5 km of the outfall (Sandilands, 1977).

Many studies have been conducted concerning the effects of fiber from pulp and paper industry on aquatic organisms. Suspended conifer groundwood fiber may be an important factor limiting the survival of young-of-the-year walleye in natural waters below paper mills during periods of low dissolved oxygen concentrations. MacLeod and Smith (1966) found that fibers in pulp mill effluents impaired both the oxygen uptake and swimming ability of fathead minnows. Smith et al. (1966) reported that cellulose fibers induced a stress response in fish - manifested as increased rate of metabolism, decreased hemocrit value, and an increase in the number of mucous cells in the gills. These factors may have deleterious effects on survival. Under environmental stresses, such as high temperatures or low oxygen, these results suggest that suspended fiber loads may decrease survival rates or reduce fish production in natural habitats. Colby and Smith (1967) found that fiber released from paper mills forms sludge mats as far as 62 miles below outfalls and creates oxygen deficiencies and dissolved sulfide concentrations near the sludge-water interface that are lethal to early life history stages of fish and some fish-food organisms. Smith and Kramer (1963) found that polluted water in Rainy River resulted in *Sphaerotilus* growths on the walleye eggs which prevented successful emergence of fry and a high mortality rate. Smith and Kramer's studies indicate that the deleterious effect of suspended wood fibers of paper-mill origin on walleye egg survival is small and that mortality in water carrying mill effluents at levels observed in the Rainy River is due primarily to *Sphaerotilus* growths and, in some lesser degree, to toxic or oxygen-demanding bottom deposits of fiber.

5.4 DAMMING

Modifications of Lake Superior levels began in 1888 with man-made obstructions in the St. Marys River channel. By 1912, reduction in the river's discharge capacity had raised the lake level by 0.18 m. The International Joint Commission specified water level limits of 183.98 and 183.52 m for Lake Superior in 1914. The Commission was mandated to prevent the manipulation of lake levels for power and navigation benefits at the expense of riparians but they were meant only to serve as goals (not to be strictly adhered to during high water levels). The water levels of Lake Superior have decreased 0.5066 m from 1903 to 1955 (Table 7). The elevation of Lake Superior was 187.2972 m in the International Great Lakes Datum of 1955 (Hartmann, 1988). The levels of Lake Superior at Thunder Bay for the months of April and May from 1940 to 1960 (Figure 7) indicate low levels from 1954 to 1960. The low water levels may have affected the year-class strength of the walleye in these years.

On a more local level, the modification of the Nipigon River began with the construction of the Cameron Falls dam and generating station in 1920 (Figure 8). The Alexander dam was built in 1930 and the Pine Portage dam in 1950, respectively (Table 8). The actual construction of the dams including the addition of materials to the river and increased erosion with possible damaging effects on the fish populations. Sedimentation as a result of erosion or decreased water flow can cause egg mortality during the incubation period of the walleye. The decreased oxygen results in lowered egg survival (Machniak, 1975). Dumping of surplus cement (Dampier, pers. comm.) during the construction of the dams would be detrimental to the walleye population. The diversion of the river during construction and the flooding after completion would increase nutrient loading and add organic materials to the water system. Another source of erosion was added in 1943 with the construction of the Ogoki diversion northeast of Lake Nipigon. An incredible amount of material eroded in the first four years of operation (1943-1947) at an average rate of 5 million cubic yards per year (Bridger and Day, 1976). The effects of this sediment load reaching Nipigon Bay (a distance of approximately 80 km) would appear to be negligible.

The construction of dams would also pose a barrier to migrating fish species thereby reducing the amount of suitable spawning habitat. In the case of walleye in the Nipigon Bay, the effects of the nearest dam appear minimal.

The hydro-electric development on the Nipigon River may be a source of water temperature alteration. The drawdown from the three dams located on the river is from surface water. The warmer surface water is expulsed below the dam warming the water system creating habitat more favourable to walleye (Ryder, pers. comm.) as would the increased turbidity resulting from sedimentation.

Table 7. Limits on Lake Superior water levels in metres.

	1903 datum	IGLD55
Upper limit	183.98	183.49
Lower limit	183.52	183.03
Expected high level	184.13	183.64
Expected low level	183.37	182.88

* upper and lower limits taken from International Joint Commission (1914)
* IGLD55 refers to the International Great Lakes Datum of 1955

Source: Hartmann, 1988.

Table 8. Hydro-electric development on the Nipigon River.

Year	Development
1920	Cameron Falls dam and generating stations, 4 units
1926	Cameron Falls extension (Units #5 and #6)
1926	Virgin Falls storage dam
1930	Alexander dam and generating station, 3 units
1945	Alexander extension (Unit #4)
1950	Pine Portage dam and generating station, 2 units
1950	Virgin Falls dam flooded out, partially removed to aid navigation
1954	Pine Portage extension (Units #3 and #4)
1958	Cameron Falls extension (Unit #7)
1958	Alexander extension (Unit #5)

Source: Near, 1982.

Water level fluctuations on the Nipigon River system resulting from the dams present have had considerable effect on the fisheries of the Nipigon River. The brook trout of the Nipigon River are particularly affected during the drawdowns in late December through to April while their eggs are incubating (Swainson, pers. comm.). Machniak (1975) notes that the water levels and discharges may have an adverse effect on walleye if the spawning areas are shallow but for the most part they are less influenced by water levels during the spawning period than other shallow water spawners. The walleye usually spawn in depths below the effects of water level fluctuations. High discharges can also increase the success of spawning by providing optimum conditions during incubation or promoting first year growth (Machniak, 1975). Data has been recorded for discharges of the Nipigon River from 1926 to 1949 below Virgin Falls and from 1950 to present at Pine Portage. From 1927 to 1950 the monthly mean discharge of the Nipigon River for April and May was 285 and 301 cubic metres per second, respectively. The discharges of the Nipigon River into the Nipigon Bay can be interpreted using the data from the Virgin Falls dam from 1940 to 1950 and the data from the Pine Portage dam from 1950 to 1960 (Figure 9). Figure 10 demonstrates the daily fluctuations for the months of April and May in 1961.

Presently, flow agreements are being negotiated between the Ministry of Natural Resources and Ontario Hydro to provide flows conducive for the spawning and incubation of brook trout on the Nipigon River. This agreement will reduce extreme fluctuations in water levels to the benefit of all the fish species present.

5.5 DREDGING

In 1908, a transport network was put in place between the mouth of the Nipigon River and Lake Nipigon to carry supplies for the construction of the National Transcontinental Railway, north of Lake Nipigon. It was during this period that a large dredge was engaged in deepening the channel into Nipigon Bay, so that the larger freighters laden with rails, could tie up alongside the wharf at the Red Rock Post (Todd, 1977). When the Canadian Northern Railway (now the Canadian National Railway) built its line through Nipigon in 1912 it created its current roadbed by extending the shoreline into the river, and by building a retaining wall and a causeway, thereby creating the lagoon (Figure 11) (Todd, 1977).

Figure 7. Monthly mean water levels in metres for the months of April and May during the time period from 1940 to 1960. The readings are taken on Lake Superior at Thunder Bay.

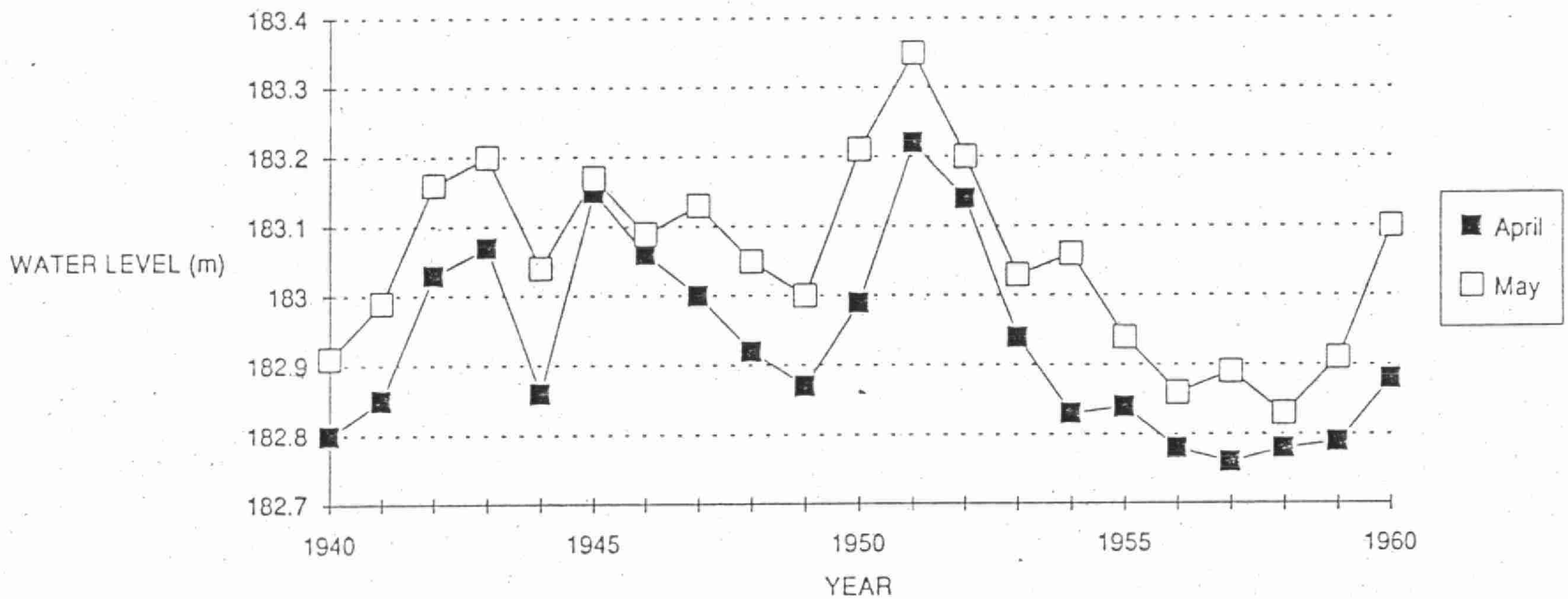


Figure 8. Map illustrating the Hydro-electric Power Commission generating stations on the Nipigon River.

Source: "Pine Portage Generating Station: Nipigon River", 1950.

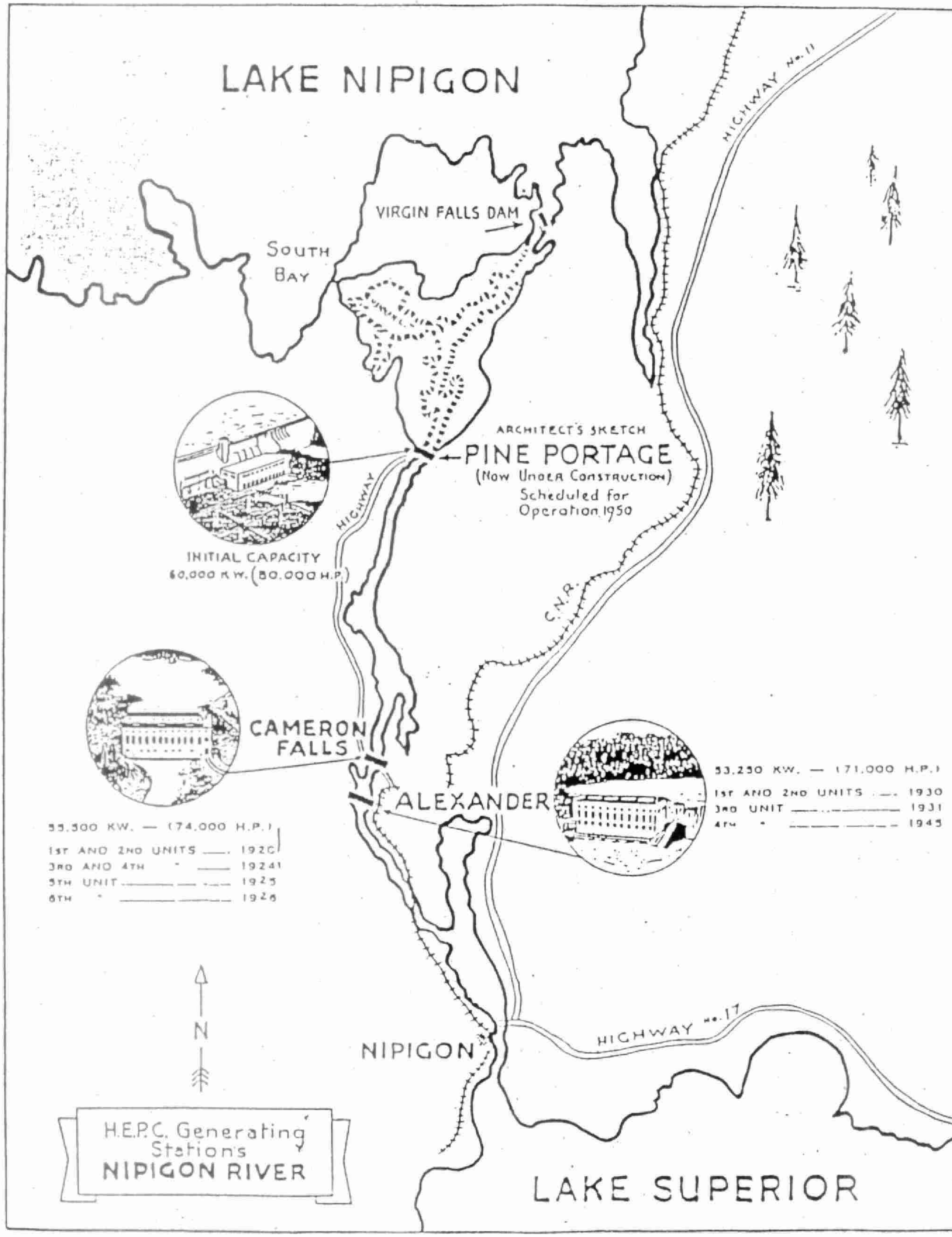


Figure 9. Monthly mean discharge of the Nipigon River measured in cubic metres per second for the months of April and May, 1940 to 1950 (below Virgin Falls) and 1950 to 1960 (at Pine Portage).

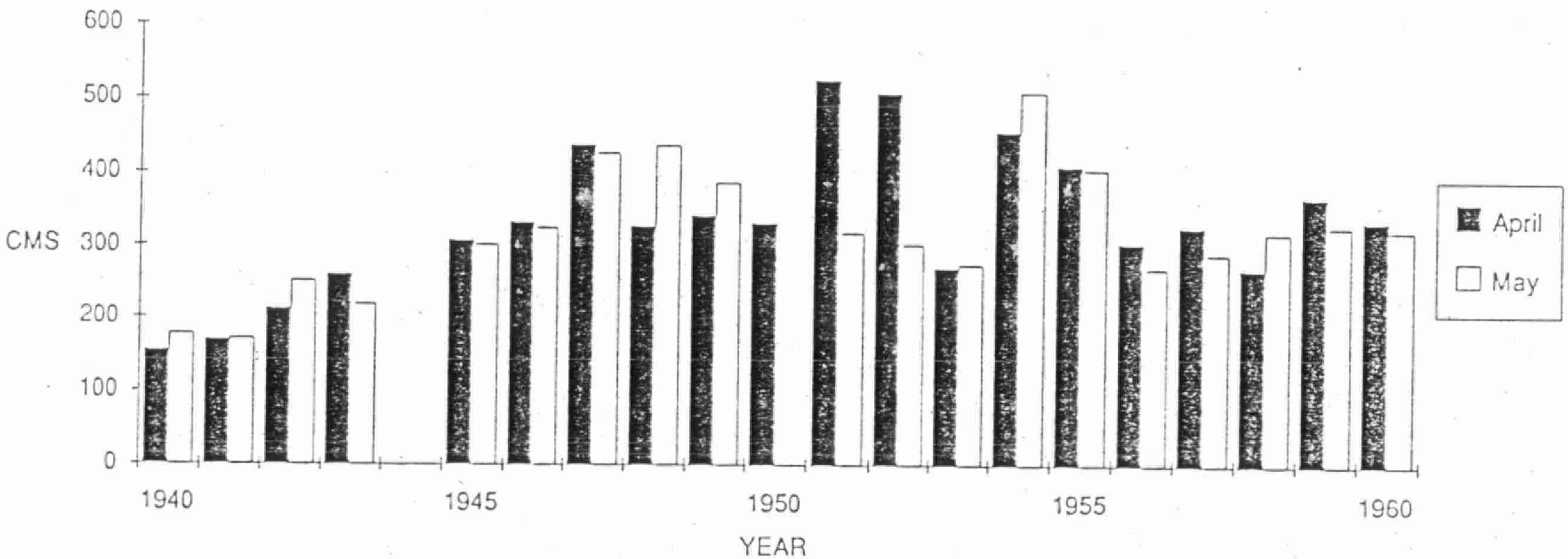
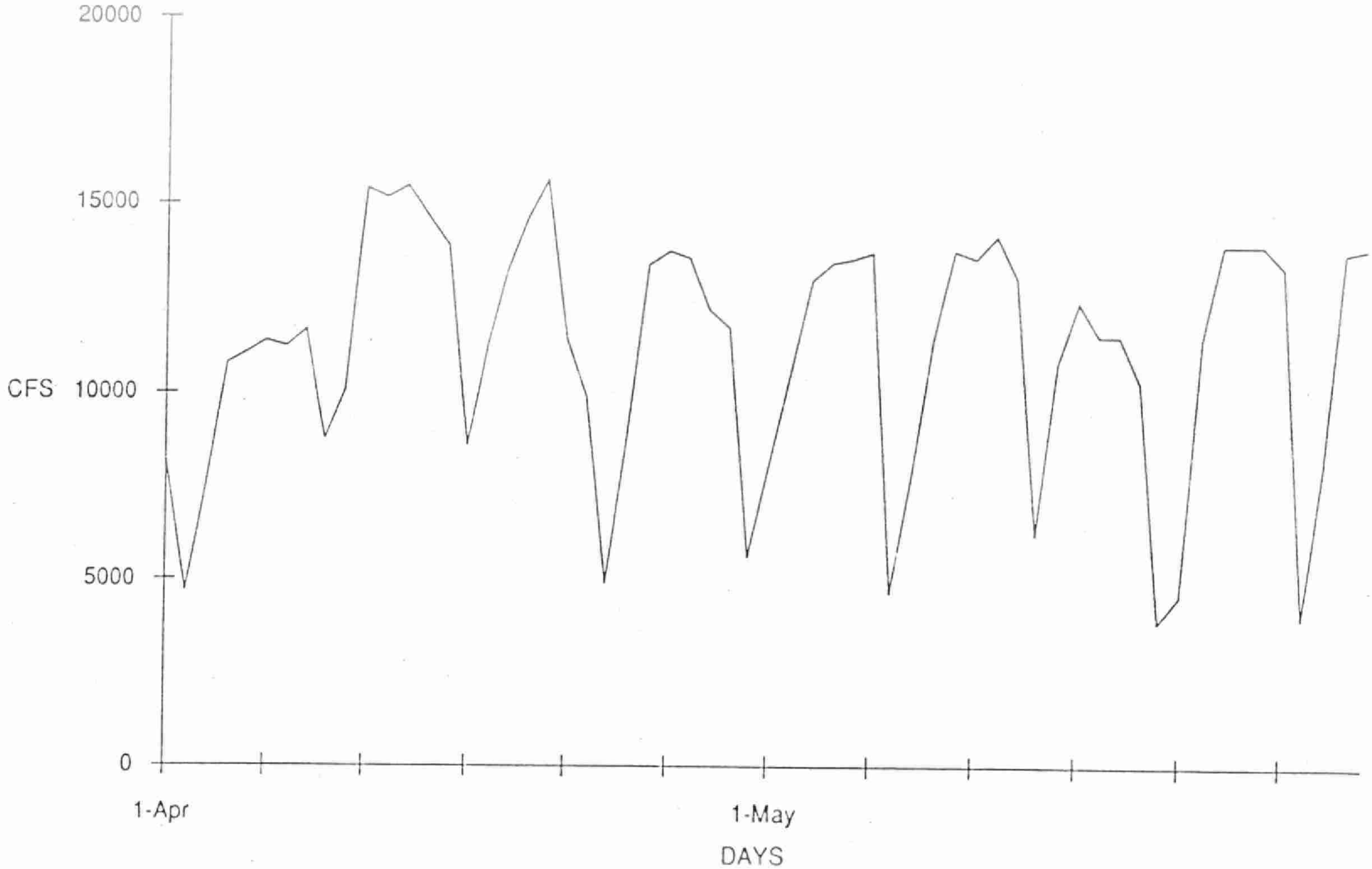


Figure 10. The discharge of the Pine Portage Generating Station for the months of April and May, 1961, measured in cubic feet per second.



6. WATER QUALITY

6.1 WATER USES AND TREATMENT

Lake Superior water, via Nipigon Bay, is used for municipal (Red Rock) and industrial (Domtar) purposes. The water is filtered and chlorinated before being piped to Red Rock's 2,650 residents at a rate of 1000m^3/day. The source of domestic water for the townsite of Nipigon is the Nipigon River. Domtar, the principal consumer of water from the bay, uses 95000m^3/day for industrial purposes (Vander Wal et al., 1989).

Downstream from the town of Nipigon the water pollution control centre discharges its effluent into the Nipigon River. Before the plant was built, sewage drained directly into the area known as the lagoon (Figure 11). This portion of the river was formed when the Canadian Pacific Railway was built. The local residents of Nipigon noted that the fishing was excellent in the lagoon prior to the 1950's. Jiggs McInnes (pers. comm.) notes that in the 1940's one could catch their limit of six walleye in the lagoon in 10 or 15 minutes. The water pollution control plant was built in the late 1950's and the outflows were relocated to their present site (Figure 11) on the Nipigon River. By the 1976 the small plant was overloaded and an expansion was required. The plant was replaced with a 1,630 m^3/day primary treatment plant and the chlorine contact time was increased. The Township of Red Rock operated an inadequate communal septic tank system until 1978. This was replaced with a primary treatment plant with a capacity of 1,270 m^3/day. Currently, the town of Red Rock discharges approximately 400 m^3/day of effluent, following primary treatment at the plant (Figure 12). The concentrations of BOD_5 and suspended solids are 35 mg/l. The loading of BOD and suspended solids are 30.0 and 32 kg/day for Red Rock and Nipigon, respectively (Vander Wal et al., 1988). Currently, effluent from the plant meets the requirements for a primary treatment facility. Effluent loadings for the major sources discharging into Nipigon Bay are listed in Table 9.

T. W. Beak Consultants (1969) reported an average suspended solids loading of approximately 47 t/day in 1969 before modifications took place at the Red Rock mill. In 1972, an external clarifier was installed for the removal of fibre from wastewater (Kelso et al., 1977). In 1974, Domtar installed a blow heat recovery system and a turpentine recovery system to collect and remove turpentine and condensible organics from the digester blow gases (Vander Wal et al., 1989). At this time, the wastewater effluent discharged into the bay contained an average of 6.51 tonnes of suspended solids per day (Sandilands, 1977). In 1976, discharge treatment at the mill was upgraded, decreasing the toxicity of the effluent and relieving some of the problem of fish tainting (Great Lakes Water Quality Board, 1985).

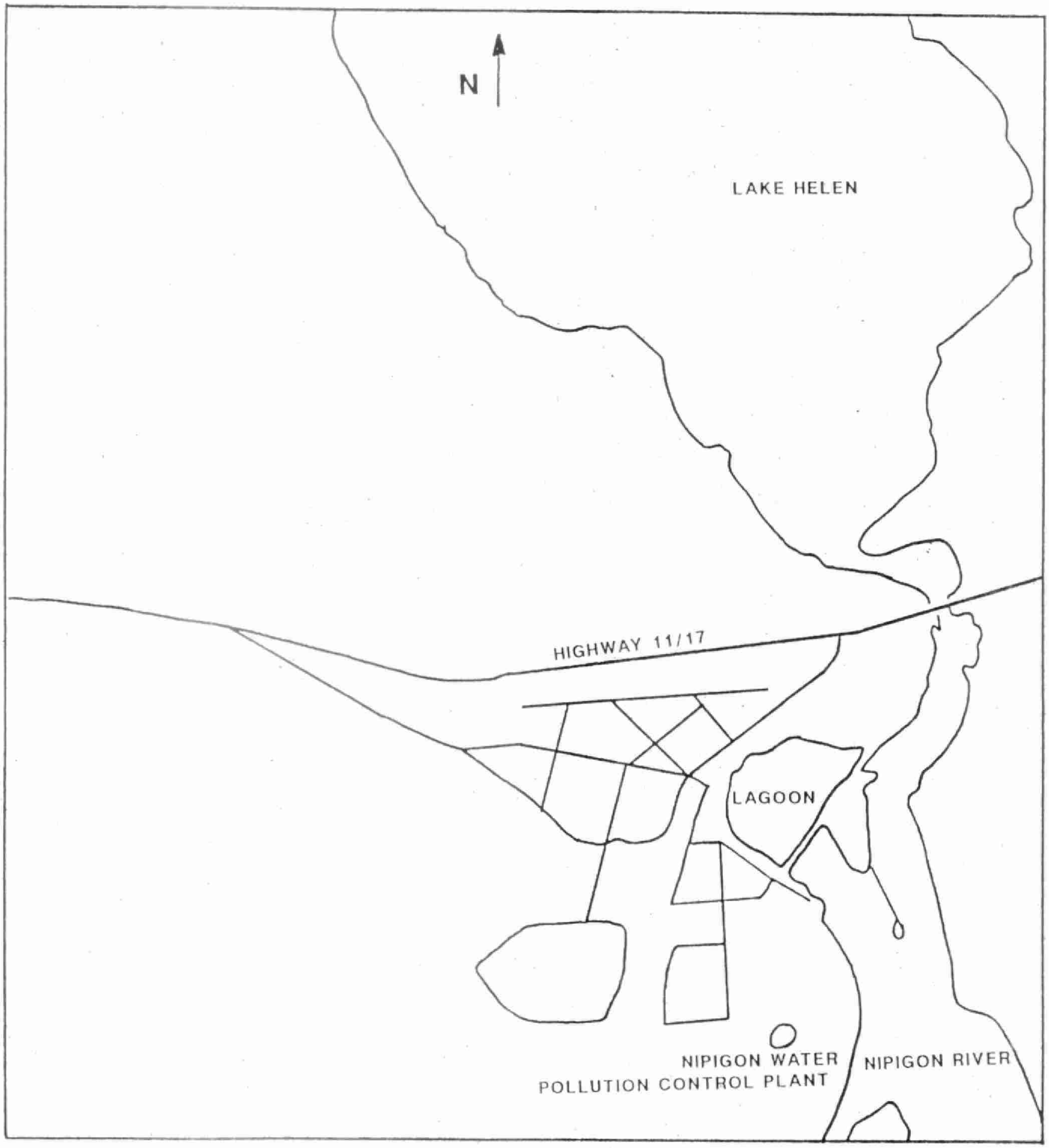


FIGURE 11. MAP OF THE NIPIGON TOWNSITE AND SURROUNDING AREA

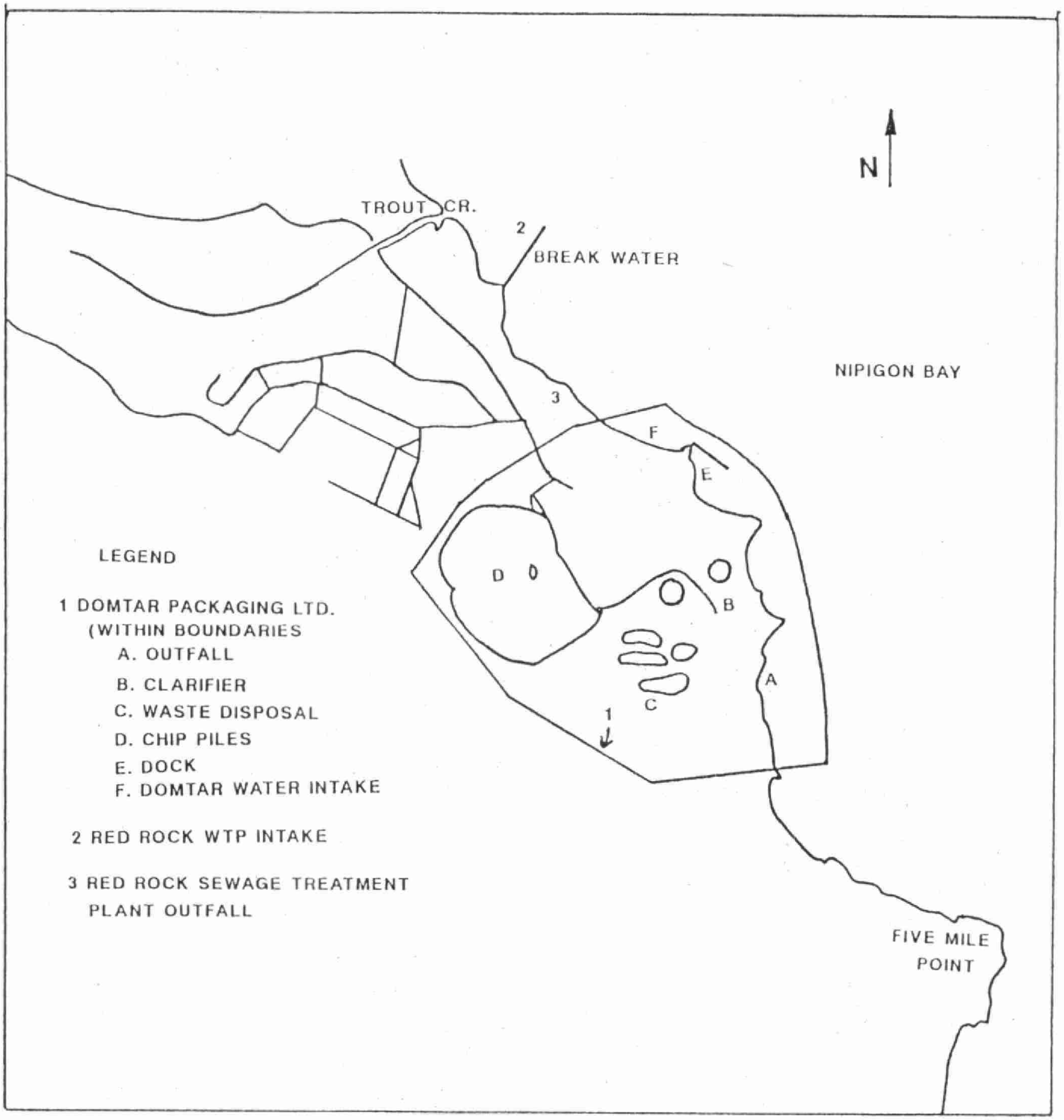


FIGURE 12: MAP OF THE RED ROCK TOWNSITE AND SURROUNDING AREA (SEPT., 1989)

In 1977, Domtar carried out a number of pollution abatement procedures as part of the black liquor spill control system. By the summer of 1978, 100% of the domestic sewage from the pulp mill, which was previously directed untreated in the total mill effluent, was directed to the Red Rock municipal treatment system (Vander Wal et al., 1989). Domtar installed an alum treatment of woodroom effluent for toxicity reduction in 1982. In 1985, a problem with coliform bacteria and the effluent plume with a high biological and chemical oxygen demand were still noted (Vander Wal et al., 1989). The most significant improvement in the mill effluent since 1972 has been the decrease in suspended solids from 17.5 mt/day in 1972 to 5.0 mt/day in 1985 (Vander Wal et al., 1989).

Currently, the Domtar mill has an approximate capacity to produce 600 tons of kraft liner board and 175 tons of newsprint per day. Domtar discharges an effluent volume of up to 85,000 m^3/day into Nipigon Bay. Control orders requiring a reduction in BOD, suspended solids, and toxicity were issued to Domtar in 1976 and in 1980 (Vander Wal et al., 1988). An additional Control Order imposed on the Domtar mill in 1986 limits the BOD, suspended solids and toxicity of the effluent discharged to 23.0 tonnes/day, 5.5 tonnes/day, and an LC_{50} of 100% respectively. These limits were based on a combination of Federal and Provincial requirements. An additional Control Order was issued to Domtar Packaging in 1989, in order to address the problem of AOX (chlorinated organic compounds). The order states that these compounds should not exceed 2.5 kg per air-dried metric tonne of bleached kraft pulp.

6.2 WATER QUALITY

German (1968) conducted a biological survey of Nipigon Bay for the Ontario Water Resources Commission. Physical, chemical and biological parameters of water quality were examined on the Lower Nipigon River and Nipigon Bay in May, 1966 and August, 1967. At this time the effluent from the mill entered the bay without any significant treatment of wastewater. Concentrations of phenols in fish flesh made some commercial catches of lake whitefish and walleye harvested in western Nipigon Bay during the early 1960's unmarketable.

German's (1968) report was conducted mainly in response to complaints regarding tainting of fish flesh and other issues associated with the waste outfall of the newsprint mill in Red Rock. By this time the commercial exploitation of walleye was no longer feasible due to declining numbers. The commercial fishermen were having trouble marketing the other commercial species due to unnatural taste (Table 10). German (1968) has taken some direct quotes from letters by the Association of Commercial Fishermen of Thunder Bay District.

"Where the Yellow Pickerel have gone elsewhere to spawn and inhabit, the Whitefish are not so choosey. The Whitefish are still in and around the polluted area but there is no sense catching them as they are not saleable."
"Direct losses were incurred by Mr. Gordon Dampier in 1961 of $2,500 when his Whitefish were rejected and dumped. Mr. Harold Dampier experienced $500 in losses in like manner. These men were told by the Baltimore Fish Company not to ship any in the future. Other fishermen in this same family along with the two mentioned commenced shipping to Kemp Fisheries of Port Arthur and were similarly told the same thing, however, with a proviso that the shipper guarantee his fish be of an edible quality. Kemp Fisheries in their advice to these men related that their customers in Detroit and Duluth refused to buy anymore Canadian Fish as their customers became nauseated with these fish".

The Association of Commercial Fishermen maintained that wastes from the Domtar Newsprint Limited were responsible for direct money losses to their members. In addition, the changes in the fishery of Nipigon Bay at this time raised conjecture concerning a possible relationship between kraft mill wastes which were discharged to Nipigon Bay and the decline of the walleye population (German, 1968).

German (1968) found that the mill effluent did not grossly alter the overall chemical quality of Nipigon Bay. The threshold odour tests indicated that a plume of odorous wastes extended southward from the effluent of Domtar Newsprint Limited to a station located off of Five Mile Point. An abnormally high threshold value was obtained 100 feet south of the discharge and an offensive level was present off Five Mile Point. The bottom fauna of Nipigon Bay was also sampled. The pollution intolerant mayflies were not present in a semi-circular area surrounding the Red Rock Mill and in the centre of the westerly channel flowing to Nipigon Strait. Sludgeworms were present in low densities throughout the bay, but were only abundant at stations devoid of the intolerant forms. Sludgeworms respond positively to organic pollution but may be limited if the pollution is toxic. The low densities of sludgeworms and absence of other taxa in the immediate vicinity of the mill were suggestive of a toxic environment. Organic pollution was indicated by an increase in density of sludgeworms further out from the discharge area. 111 fish from the vicinity of the mill were sampled for foreign flavour. Of these fish, 92% were rated as having a foreign flavour and 71% were considered to possess a definite to strong flavour. None of the fish from MacInnes Point, Caribou Point, Outan Island or the Clay Banks were considered to be tainted. As recently as 1983, the phenol, guaiacol, was detected in the bay within 700 m of the combined water pollution control plant and Domtar discharge above levels which taint fish flesh in laboratory studies (Kirby, 1986).

German (1968) shows that changes in the aquatic environment and corresponding shifts in aquatic populations have been demonstrated in Nipigon Bay. Water quality changes in the vicinity of the Red Rock Mill have altered the bottom fauna from pollution-intolerant to tolerant forms which may result in a loss of preferred food for game fishes.

A study undertaken by Domtar in 1971 involved the determination of density and diversity of the benthic macro-invertebrates as well as the type of organic debris littering the lake and river bottoms above and below the Red Rock mill. This study found that the accumulation of bark on the bottom of Lake Helen did not adversely affect the invertebrates found there contrary to many other reports. The researchers also found caddisflies at all stations except those near the mill outfall. Caddisflies are pollution-intolerant organisms, and mayflies are not found below 75 feet therefore indicating that there is little evidence of any alteration of the benthic environment due to soluble "pollutants" either upstream or downstream from the mill (excluding the immediate vicinity of the mill).

6.3 RESEARCH PROGRAMS, NIPIGON BAY

An intensive research program was conducted on Nipigon Bay during the summer of 1974. Johnson's (1977) data suggests that energy use and uptake of oxygen in aerobic degradation of organics and sedimentation of particulate matter and its deposition apparently were not proceeding at rates deleterious to the receiving water in Nipigon Bay, except very locally. Fox (1977) noted that the natural production of fatty acids is evident thereby reducing the effect of the greatly diluted effluent excepting the immediate 300 m. Sandilands (1977) results determined the effects of the mill discharge on the chemical and biological parameters. He found that the mill effluent lowered the pH and increased the organic matter in the sediment in a localized area 1.5 km from the point source. Above average concentrations of total sulphur and mercury were associated with the increased organic loading. The presence of mercury may have originated from historic discharges, as the use of mercury based slimicides was discontinued approximately a decade ago (Vander Wal et al., 1989).

Conditions at the pulp and paper mill at Red Rock resulted in intense aggregation there and caused species dominance to shift to sucker at the mill discharge from perch in unaffected areas (Kelso, 1977). Fish released in areas with high discharge showed disorientation and those released in areas with low discharge showed an immediate avoidance reaction. Although the individual fish tended to avoid areas of altered water quality, the community aggregated at Red Rock in response to, perhaps, increased production of benthic macroinvertebrates (Kelso, 1977). Studies by Leslie and Kelso (1977) found that larval fish either were not greatly influenced by plume conditions or they were transients.

The fishes of Nipigon Bay have been subject to complaints of unpleasant odour and taste on more than one occasion. For this reason contaminant studies have been undertaken. A study involving the analysis of contaminants in the fishes of Nipigon Bay was undertaken in 1974 by Kaiser (1977). Three species of fish, caught at various distances from the mill, were analyzed for organic contaminants. Fishes from all sites contained residues of polychlorinated biphenyls and DDE. Most samples also contained hexachlorobenzene and several samples contained phthalic acid esters. Dehydroabietic acid was observed in the three species of fish sampled in the direct vicinity of the mill discharge. The major source of this acid and other resin acid derivatives is known to be kraft pulp and paper mill effluents (Kaiser, 1977).

During September of 1977, the Kraft Paper and Board Division of Domtar Packaging Limited, Red Rock requested assistance from the MNR in obtaining various specimens of fish from Nipigon Bay. The purpose of this was to determine tainting of the flesh, if any, by the effluent pumped into Nipigon Bay by the Kraft Mill located at Red Rock. Sufficient numbers of fish were not caught to enable Domtar to carry out the necessary research, however, many various species of fish were obtained (Nipigon District, files).

6.4 RECENT STUDIES

The most recent study on the water quality of Nipigon Bay was conducted by the Ministry of Environment in 1983. Critical findings of this study relate to chemical quality of waters in the vicinity of the mill, toxicity to fish and effluent plume configuration. The 1983 survey indicated that the water quality in those areas of Nipigon Bay impacted by the Red Rock mill have improved substantially, in relation to the quality found during earlier surveys. Despite changes and improvements in water quality, violations of the Provincial Water Quality Objectives for phenols, total coliform bacteria, and several metals were observed in a number of locations (see Vander Wal et al., 1988 for detailed information on water quality). Other pollutants of concern are the resin and fatty acids since they are the principal substances responsible for toxicity in pulp and paper mill effluents. Several resin and fatty acids were found in receiving waters at concentrations which are known to be toxic to fish. Poor dispersion of the effluent plume (Figure 13) in Nipigon Bay appears to be a significant problem (Vander Wal et al., 1988).

The conventional parameters from the 1983 results indicate that concentrations of reactive phenols and copper exceeded the objectives over large areas. Levels of cadmium, iron, mercury, and zinc exceeded objectives at only those stations closest to the mill. The results also indicated that the mill is the major point source of organic contaminants to Nipigon Bay waters.

Many compounds were detected at levels above objectives or guidelines, especially at sites closest to the mill/water pollution control plant outfall. The presence of dioxins was not found in the sampling of effluent conducted in 1987. Bacterial levels in general, have been highest near the mill/WPCP outfall. High levels were also discovered near the Nipigon WPCP discharge. Exceedences of water quality objectives for bacteria were few and concentrated near the mill/WPCP outfall.

Table 9. Average effluent loadings (tonnes/day) of conventional pollutants from major sources discharging to Nipigon Bay.

	Domtar Packaging		Red Rock WPCP		Nipigon WPCP	
	1983	1988	1983	1988	1983	1988
BOD_5	16.6	16.57	N/A	0.127	0.087	0.104
Suspended Solids	4.95	4.84	N/A	0.057	0.063	0.088
Phosphorus	N/A	0.046	N/A	0.0006	0.0059	0.0053
Flow (m^3/day)	93,100	96,800	N/A	895	1,660	1,770

N/A - not available

* Source: Vander Wal et al., 1989.

Table 10. Incidence and intensity of foreign flavour in fish samples from Nipigon Bay, August, 1967.

Collection Site	# of Samples	0	+	++	+++	Total Positive	Definite or Strong
MacInnes Pt. (control)	39 100%	26 67%	7 18%	5 13%	1 2%	13 33%	6 15%
Red Rock Mill	111 100%	10 9%	23 21%	30 27%	49 45%	101** 92%	79** 71%
Outan Island	39 100%	27 69%	10 26%	1 2%	1 2%	12 31%	2 4%
Clay Banks	39 100%	30 77%	7 18%	2 5%	0 0%	9 23%	2 4%

* 0 - no foreign flavour present
+ - foreign flavour - barely perceptible
++ - foreign flavour - definite
+++ - foreign flavour - strong
** - significantly different from control at 1% level

Source: German, 1968

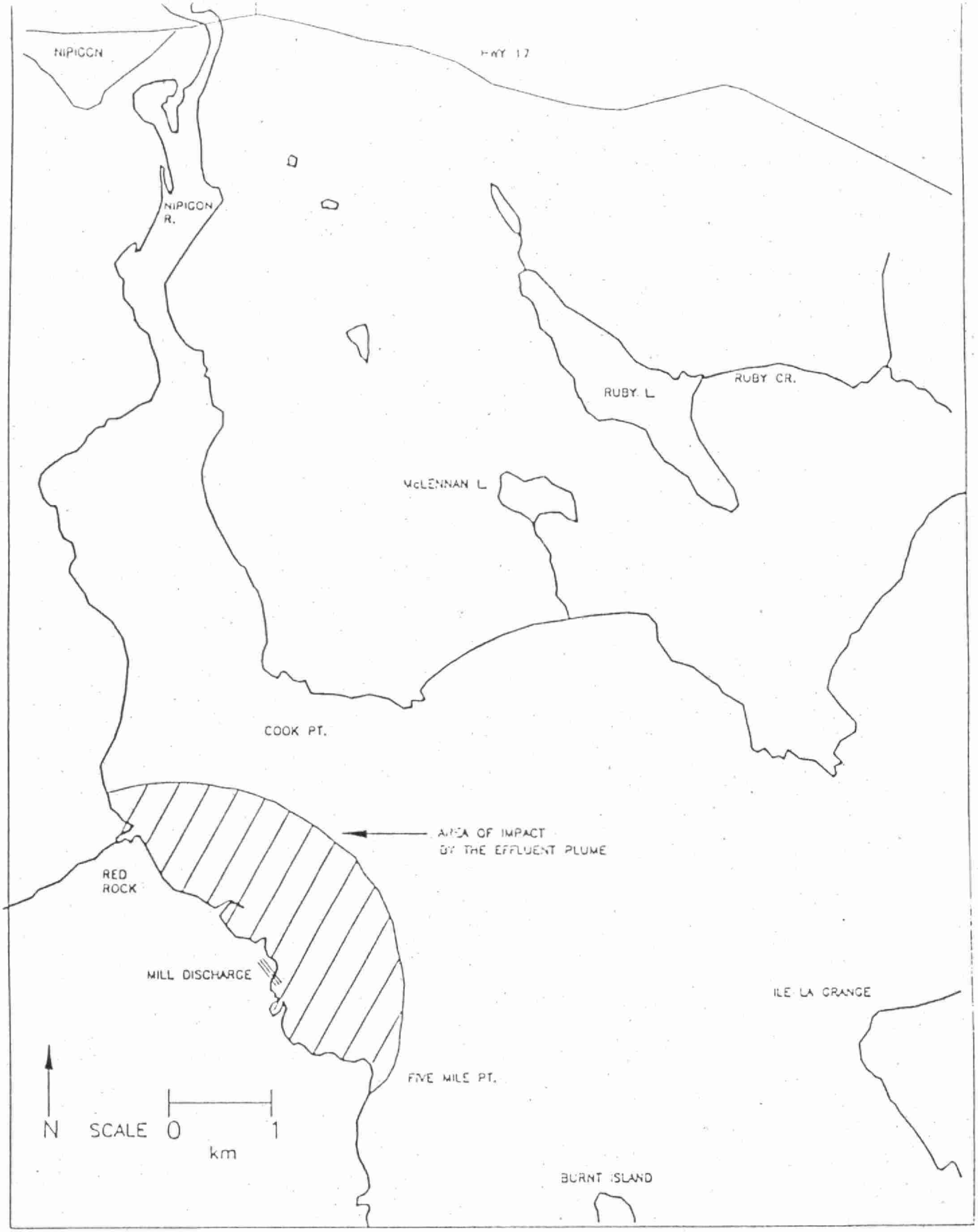


Figure 13: Area of Effluent Plume Impact in Nipigon Bay (Zorzes, 1986)

7. CLIMATIC FACTORS

If the spawning grounds of a species have been progressively reduced to a few vulnerable locations by intensive fishing or by environmental degradation, small climatic deviations may then lead to periodic failures of the reproductive process. Of course, climatic fluctuations alone may inhibit the reproductive process as well as reproductive success (Regier and Hartman, 1973).

7.1 WATER LEVELS

Water levels can play an important role in the development of walleye eggs if extreme high or low levels occur during crucial periods (Machniak, 1975). Hydro-electric dams on the Nipigon River may affect the spawning population under the highway bridge but probably would have little effect on those in Nipigon Bay. Walroth and Schraeder (1981) state fluctuating water levels as a major factor in the high egg mortalities found during the Jackfish River walleye introduction project. The eggs were often swept down the river possibly landing on unsuitable substrate. The eggs planted in 1980 were left high and dry after the spring flood waters had subsided and spring temperatures were abnormally high. Walroth (1980) speculates as to whether the variable spring water levels could have been a causative factor in preventing a spawning run from developing originally on the Jackfish River, when walleye were plentiful in Nipigon Bay. Many people suggest that walleye may have spawned in the Jackfish River but there is no evidence to support this theory.

While nature plays the predominant role in lake level fluctuations, the influence of human impacts becomes more of a concern when water levels are either at the extreme high or low part of their cycle. The levels of Lake Superior fluctuate both seasonally and on a long-term basis. The seasonal regimes are reasonably predictable: the lake normally fluctuates about 30 cm annually, being lowest just before the snow melts in the spring and highest in September. More spectacular changes in the lake levels result from short-term oscillations induced primarily by winds and atmospheric pressures. These factors may raise or lower the lake level along a given shore by as much as one metre within a period of a few hours (Rasid et al., 1989). The prevailing westerly winds would intensify these factors in Nipigon Bay.

Prior to the levels experienced during 1985 and 1986, high water levels were experienced at least during three other periods: 1972-73, 1950-51, and 1915-16 (Figure 14). Extremely low water levels occurred in 1924-25 and a gradual decline is evident for approximately six years following the peak in 1950-51. Lake Superior's natural water balance resulting from inputs of precipitation, ground water, surface runoff, and stream flow override the effects of human regulation systems (Rasid et al., 1989).

The increased levels of precipitation in 1950 were noted by many of the local residents in Nipigon although they did not feel that it had any impact on the walleye decline in Nipigon Bay. Dupuis (pers. comm.) noted a major flood about 40 years ago which was caused by an unusual amount of precipitation; the flood redirected the small stream through Nipigon. Previously, the stream inflow was at the wharf but now it flows out at the sewage treatment plant. The effect of extreme water levels would probably only have an effect if they occurred during the incubation of the walleye eggs (April 15 to June 30). The lower water levels would likely have more of an effect on incubating eggs due to desiccation than high water levels would have.

The effects of lake levels as well as temperatures on the year-class strengths of walleye and yellow perch in four inland lakes were studied. Kallemeyn (1987) found significant positive correlations between lake level and walleye year-class strength in three of four lakes sampled.

7.2 TEMPERATURE

A series of weak year classes may have been a contributing factor in the walleye decline in Nipigon Bay. Wolfert (1981) found that a rapid rate of rise in water temperature during spawning and incubation was positively correlated with the strength of walleye year classes in the New York waters of Lake Erie.

Busch et al. (1975) speculated about reasons why a rapid rate of warming caused greater year-class success in western Lake Erie. They suggested that the detrimental effects of low oxygen, siltation, disease, predation and chances of strong winds generating currents that wash eggs off spawning reefs and onto unfavourable habitat would be reduced as the incubation period was shortened. One other beneficial aspect of rapidly warming waters during the spawning and incubation period, with little or no temperature reversals, is that a comparatively small walleye population of brood fish would be fully ripe and ready to spawn over a short period of time. The maximum number of spawners would be on the spawning grounds at the same time, thereby increasing the chances of fertilization (Wolfert, 1981).

Kallemeyn (1987) found that the largest year-classes of both walleye and yellow perch were produced when the temperatures were warmer and more stable.

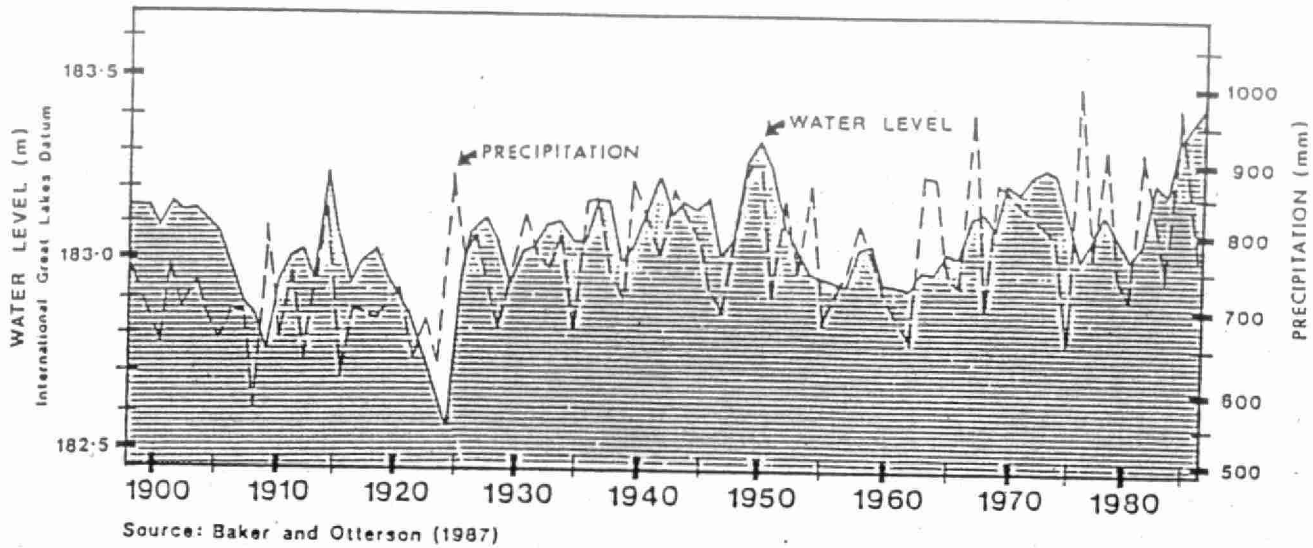


Figure 14: Lake Superior water level and precipitation, 1900-1986. Note high water level periods in 1972-73, 1950-51, and 1915-16.

8. SEA LAMPREY CONTROL

Sea lampreys *(Petromyzon marinus)* were first reported in Lake Ontario in 1835 (Lark, 1973). It is not known whether sea lampreys were native to Lake Ontario or whether they reached the lake via the canal system that was constructed in the early 1800's. Niagara Falls served as a natural barrier to migration into the upper Great Lakes until the construction of the Welland Canal in 1829. It provided a bypass that linked Lake Ontario to Lake Erie (Pearce et. al., 1980), and the sea lampreys then spread throughout the Great Lakes. Although the lampreys may have been present before they were actually noted their presence in the Great Lakes for the first time is noted as follows: Lake Erie in 1921 (Dymond, 1922); Lake Huron in 1937 (Applegate, 1950); Lake Michigan in 1936 (Hubbs and Pope, 1937); and Lake Superior in 1938 (Smith and Tibbles, 1980).

Each of the methods of sea lamprey control had, to a varying degree, effects on resident fish stocks and migratory species which used the streams for spawning (Dahl and McDonald, 1980). Methods of control consisted of mechanical barriers, electrical barriers, and chemical lampricides. More recently, barrier dams have been proposed as an option (Sea Lamprey Control Centre, pers. comm.).

Adult sea lamprey begin significant movement into preferred streams to spawn when water temperatures approach 10^{o}C. Spawning takes place from April until the end of July; the peak spawning period occurs in June and July (NRCC, 1985). There are three basic requirements for successful spawning. Gravel in the stream bed must be from 0.5 to 5.0 cm in diameter, and small amounts of sand should be available. The current must be unidirectional over the nest at a velocity of 0.3 to 1.7 m/second. The water temperature should be between 15.6 and 21^{o}C (NRCC, 1985). Adult lamprey die after spawning. The eggs take approximately 18 to 21 days to hatch. The ammocoetes drift downstream and burrow into the soft stream bottom where they remain for approximately 3 to 17 years. Young adults move downstream into lakes where they prey on many species, especially lake trout, salmon, whitefish, herring, and chub. The parasitic feeding lasts for 12 to 20 months, during which time the adults increase in length from 15 to 45 cm on the average. They then return to the streams to spawn (NRCC, 1985).

The Lake Superior lake trout population production prior to 1952 was 4,500,000 pounds but by 1955 it had dropped to 3,500,000 lbs./year (Ann. Rep. of the Fishery Research Board of Canada, 1955).

> "If lamprey populations remain unchecked lake trout will no longer be available in commercial quantities by the 1960's" (Ann. Rep. of the Fishery Research Board of Canada, 1955).

8.1 ELECTRICAL BARRIERS

Sea lamprey control began on Lake Superior in 1953 with the installation of mechanical traps and electrical barriers to prevent the adults from ascending and spawning in the streams. Fyke nets upstream and downstream from electrical barriers minimized the accidental electrocution of fish other than lamprey. The barriers were in operation during the peak run of lamprey in late May and early June (Ann. Rep. Fish. Res. Board Can., 1955).

Two major problems were uncovered with respect to the effectiveness of the electrical barriers (Ann. Rep. Fish. Res. Board Can., 1959). The first concerned the repair or replacement of electrodes damaged by flood-borne debris without allowing too many lamprey to escape upstream. The second problem arose out of the fact that "the barriers killed fish as readily as they did lampreys." To minimize this unwanted mortality nets were installed across the stream below the barrier. These were large enough mesh to permit lamprey to pass but small enough to stop the average sucker, rainbow trout, or walleye ascending the stream. Barriers were also used to protect downstream migrants. Dahl and McDonald (1980) noted that some rainbow trout and suckers developed morphological damage while subjected to electric shock. Damaged vertebrae often caused disfigurement of the fish.

In 1956, 29 electrical barriers were operated on the Canadian side of Lake Superior (Figure 16). Figure 15 illustrates the locations of streams where 16 weirs were operated on Lake Superior, and tributaries with significant fish kills as a result of the sea lamprey control program (Dahl and McDonald, 1980).

The lamprey electrical barrier on the Jackfish River was in operation from April 27 to September 15, 1959 with the exception being a closure while pulp was being continuously driven in the river from May 4 to June 15. The numbers of lamprey recovered in 1958 and 1959 were 64 and 240, respectively (Fish. Res. Board Can., 1961). Operation of this barrier took place for three years.

Local residents noted that the lamprey were so bad in the late 1950's that even the suckers had scars on them and lake trout were hardly ever caught in Nipigon Bay (Skillen, pers. comm.). Skillen also suggests that the electrical weirs located on the Gravel and the Jackfish Rivers may have killed more fish than lamprey. He recalls seeing fish flying through the air when they were shocked. Contrarily, Jiggs McInnes feels that the barrier could have little effect on the walleye population because walleye also declined in other streams which did not have barriers (pers. comm.). Ryder (pers. comm.) did a rough estimate using tag returns of the number of walleye killed by the electric barrier on the Jackfish River during its first year of operation and determined approximately 700.

Figure 15. Location of streams where 16 weirs were operated on Lake Superior (dots) and tributaries with significant fish kills as a result of the sea lamprey control program. Source: Dahl and McDonald , 1980.

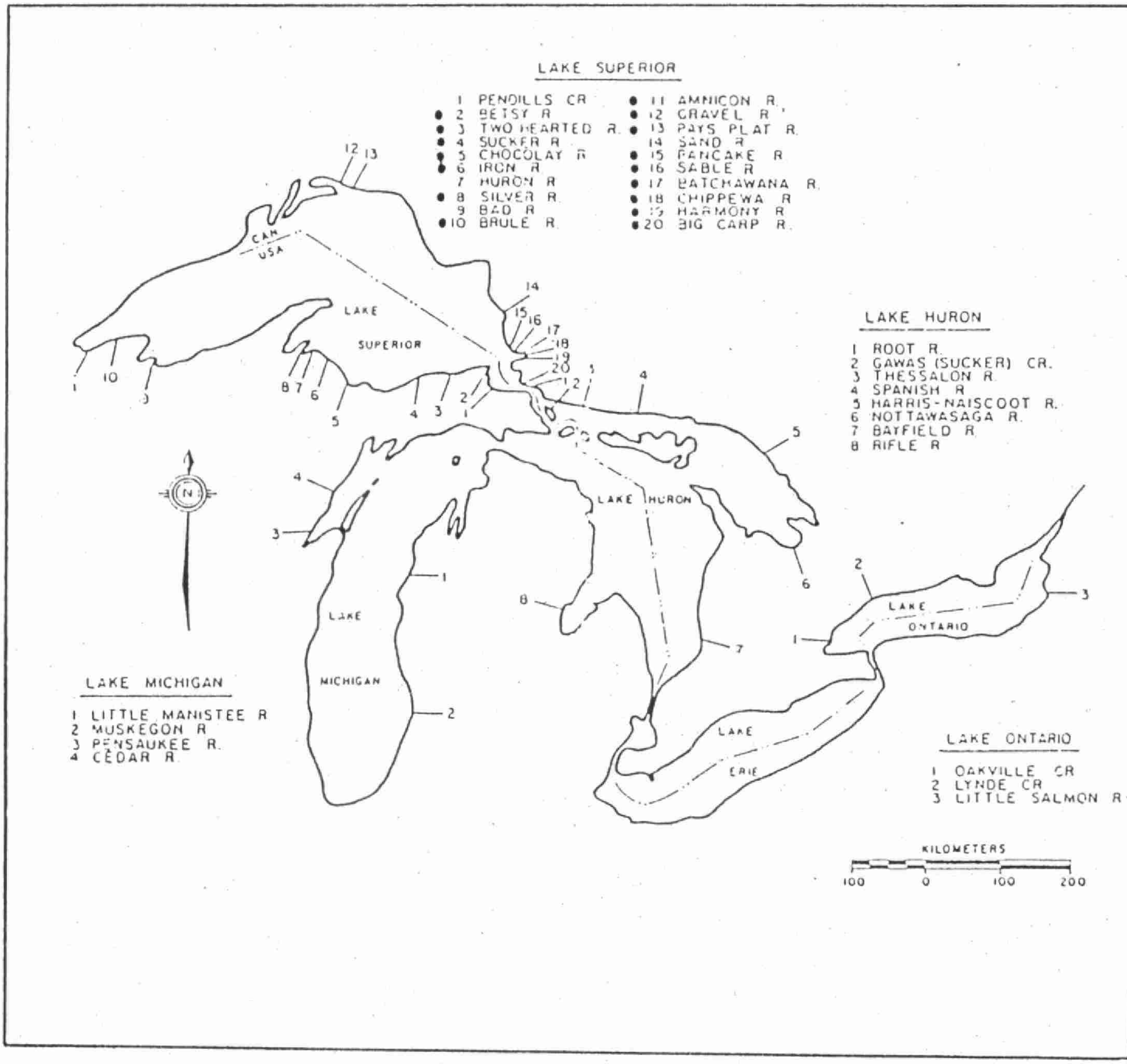
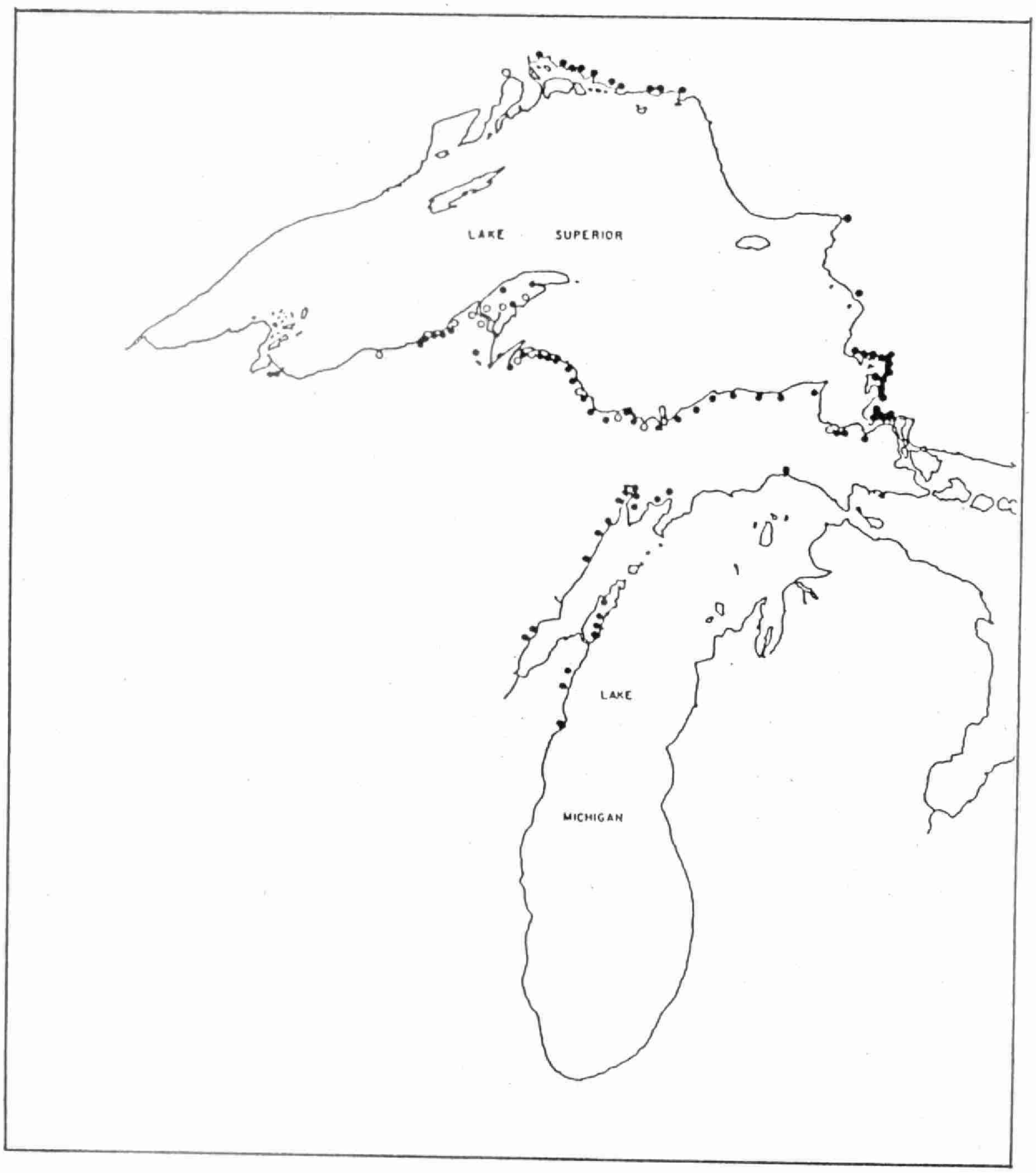


Figure 16. Electrical barriers in operation on Lakes Superior and Michigan in 1956. Standby barriers are shown as open open circles. Source: GLFC, 1959.



The weir was operated for three years and only the first year had significant mortality. Even with this mortality, Ryder (pers. comm.) does not believe that the proportion of the population killed was significant in the actual collapse of the walleye in Nipigon Bay. The electrical barriers proved to be largely unsuccessful in controlling the lamprey population and their use was discontinued in Canada in 1968 (Lawrie, 1970).

8.2 CHEMICAL CONTROL

Lamprey control measures did not become effective until after 1958, when TFM was developed. TFM and a second approved lampricide, Bayer 73, are currently licensed for control of sea lamprey in the Great Lakes. Bayer 73 is used in two formulations with different use patterns. As a wettable powder, the addition of a small percentage of Bayer 73 to TFM maintained the selective toxicity, but lowered the amount of TFM required to treat streams (Dahl and McDonald, 1980). Although this mixture is still selectively toxic, it is more toxic to both lampreys and nontarget organisms than TFM alone. Generally the mixture is used only in the treatment of large rivers or where high concentrations of TFM are necessary (NRCC, 1985). Granular Bayer is a special formulation of the wettable powder on sand granules. It is used as a survey tool, to detect and collect ammocoetes, and in limited treatments of lentic environments (SLCC, pers. comm.). Granular Bayer 73 extends the reach of control beyond the stream TFM block which dissipates rapidly in the larger water bodies. The heavy granule quickly reaches the bottom causing lamprey to surface where they can be easily collected. The amount of Bayer 73 used in both formulations is less than 1% of the amount of TFM that is applied annually in terms of respective active ingredient (SLCC, pers. comm.).

The lampricides target on the larvae which generally spend four to seven years in the soft bottoms of streams before metamorphosing and descending into the lakes. Several year-classes of lamprey could be eliminated in a single stream treatment. The treatment of streams with TFM has resulted in at least a 90% reduction in the numbers of spawning-run sea lamprey ammocoetes in the Great Lakes (Seelye et al. 1983).

Tributary streams to the Great Lakes are treated at three to ten year intervals depending on the abundance, growth and transformation predictions of the larval lampreys. The amount of TFM metered into the stream is that needed to expose larval lampreys for the required time (9, 12, or rarely 16 hour levels) and to produce a predetermined concentration of TFM. The length of exposure combined with the concentration adds up to a lethal dose for the lamprey. TFM concentrations generally range from 3 to 9 ppm (GLFC, 1985)

The possible effects of the chemicals, both short and long term, must be considered as well as the effect of the lowered water levels on major spawning streams. For example, to be economically efficient and biologically effective the flow of the Nipigon River through the Alexander Falls dam was reduced from approximately 350 m^3/s to 56 m^3/s for approximately 72 hours in 1981. The annual mean discharge through the Pine Portage Dam in 1981 was 280 m^3/s (Ont. Water Res. Comm., 1989). The effects on the bottom dwelling organisms and the fisheries must be considered.

8.3 EFFECTS OF TFM

The sensitivity of sea lamprey ammocoetes to TFM is greater than the sensitivity of other species of fish due to their inability to metabolize or change the chemical structure of TFM so it can be discharged from their bodies. There is considerable variations in sensitivity depending on species and environmental conditions. If resident fish in a stream are already stressed by some other factor such as pollutants, low oxygen levels, high water temperatures, or spawning, the effects of TFM may change dramatically (GLFC, 1985). Fish in spawning condition are usually more vulnerable to the toxicant than at other times of the year; therefore, chemical treatments are scheduled to avoid major spawning runs when possible.

The accumulation of TFM in stream bottoms was also of concern with respect to its effect on the benthos which provide a food source for game fish, such as the walleye. The extinction of a major food source could prove detrimental to fish species. The conclusions of the panel on TFM and Bayer 73 (NRCC, 1985), based on the available information, were that the use of TFM will have short term and immediate adverse effects on populations of Turbellaria, Oligochaeta and some Arthropoda. Among arthropods, this includes certain species of mayflies, caddisflies, and blackflies. Gilderhus and Johnson (1980) found that the short term impact of lampricides on invertebrates has probably been of minor importance in aquatic ecosystems. If significant mortality of some fish food items occur, they are usually confined to a small section of the particular stream system, and other food organisms are left unaffected. In most cases, a portion of the lake or stream is left untreated to provide organisms for recolonization.

Teleost fish are less susceptible to lampricides than sea lamprey larvae. If no other toxicants are present, laboratory and field data for TFM and the 98:2 mixture indicate that the most susceptible species of large fish are the suckers and the bullheads (NRCC, 1985). Menzie and Hunn (1973) found similar results (Table 11) with the walleye also having a low differential toxicity ratio. Other fish occasionally affected include the northern pike and a number of salmonids. Centrarchids are the most resistant (NRCC, 1985).

Table 11. TFM toxicity to larval lampreys and fish.

Test fish	Avg. TFM dose required to kill: 100% larval lampreys (ppm)	Avg. TFM dose required to kill: 25% test fish (ppm)	Differential toxicity (ratio)
Largemouth bass	6.3	31.5	5.0
Smallmouth bass	4.5	38.2	8.5
Bluegill	6.3	32.0	5.1
Walleye	6.7	8.3	1.3
Yellow perch	6.3	13.6	2.2
White sucker	5.7	8.3	1.5
Yellow bullhead	6.0	10.3	1.7
Blacknose shiner	6.3	19.9	3.2
Golden shiner	6.0	23.4	3.9
Fathead minnow	6.0	25.3	4.2
Rainbow trout	5.3	19.3	3.6

Source: Menzie and Hunn, 1973.

TABLE 12. Acute toxicity of TFM to larval sea lamprey, fingerling rainbow trout, and three life stages of the walleye.

	$LC_{99.9}$ (mg/L)[a]	LC_{25} (mg/L)[b]			
Experiment number	sea lamprey larvae	rainbow trout fingerlings	walleye eggs	walleye sac fry	walleye swim-up
1	2.5	8.3	> 14.0	-	-
2	2.5	9.0	-	9.8	-
3	2.5	7.6	-	-	6.3

a) Minimum lethal concentration to kill 99.9% of the sea lamprey in 8 hours.
b) Maximum concentration producing 25% kill of test organisms in 16 hours of exposure.

Source: Seelye et al., 1983.

Seelye et al. (1983) studied the toxicity of TFM on the early life stages of walleye (Table 12). They found that under normal treatment conditions the early life stages of walleye will not be adversely affected by treatments with TFM. The most sensitive life stage tested was the fry after swim-up and these fish were more than twice as tolerant of the TFM than sea lamprey ammocoetes. In summary, the results of Seelye et al., show the lamprey to be 2 to more than 5 times more sensitive to TFM than any early life stage of the walleye.

8.4 CHEMICAL CONTROL, NIPIGON AREA

The use of lampricide did not begin in the Nipigon area until 1960 with the treatment of the Jackfish River. The individual tributaries of Nipigon Bay that were treated are noted in Table 13 and illustrated on Figure 1.

On one occasion (probably during the granular bayer treatment in 1971), Bob Matchett (a resident on Lake Helen and employee of Domtar) noted five or six large northern pike floating on the surface after one of the chemical treatments on Lake Helen. He feels that this was only a small percentage of the number of fish killed due to the small area of the lake that he and his crew covered in their tug. Another local angler (Dupuis, pers. comm.) noted major fish kills the approximately the first three years (approximately 1960 to 1963) that chemical control was used. In the first year whitefish, suckers, a couple of walleye, and some pike were noted floating on the surface (Ray Dupuis, pers. comm.). This was probably during the treatment of the Nipigon River in 1964 when the federal survey crews also noted significant whitefish and sucker mortalities. On one occasion, Ray went down to do some fishing while Hydro had the water levels low in conjunction with the lampricide program. He was a bit late and the stream treatment had already been completed. He thought he saw raindrops on the water but, in fact, it was whitefish fins. The fish were belly up with their fins moving around in slow circles. Dupuis feels that hundreds of whitefish and suckers were killed by the chemical control program. Personal communication with the Sea Lamprey Control Centre indicated that treatment occurred on the Nipigon River in 1964, 1970, and 1975. Observations by the survey crews are as follows: significant whitefish and sucker mortalities were noted in the Nipigon treatment in October 1964; significant whitefish, few Percopsis, burbot, and menominee observed in the treatment in September 1970; only Percopsis mortality observed in the Nipigon treatment in August 1975. Ryder (pers. comm.) suggests that the chemical control is generally done in August therefore no walleye would be present in the lower river, rather walleye would be in Lake Superior.

The lampricide treatments on the Nipigon River were cancelled in 1979 and 1980 due to high water levels. The treatment flow on the Nipigon River is approximately 56.7 m^3/s. The flow is dictated by the economics of Ontario Hydro and the availability of the required amounts of lampricide. Hydro could not reduce flows therefore no treatments were carried out (Nipigon District files).

In 1981, lampricide treatments took place on the Jackfish River on June 26-27, and on the Nipigon River on July 2-3. Granular Bayer 73 treatments in select areas such as Mountain Bay, Cypress Bay, Helen Lake, and the lower Nipigon River and the Nipigon Bay were also conducted. Mechanical weirs were also operated on the Little Gravel and the Cypress Rivers for the purpose of capturing spawning-phase sea lamprey. These weirs were operated from Monday to Friday with the fish collected being released up or downstream. The weirs were operated until July 10 with no walleye being caught. An invertebrate sampling and dead organism collection was also conducted by Ministry of Natural Resources personnel on the Nipigon River in conjunction with the lamprey eradication program to determine if any organisms were killed by the lampricide application or by the lowering of the river. The specimens collected from the bottom sampling are shown in Table 14. On the actual treatment day, an inspection of the river between Alexander Falls and Lake Helen was carried out. A number of dead fish were observed, mostly trout-perch, some of which were in spawning condition. One cisco was also observed. Trout-perch are almost as susceptible to TFM as sea lamprey therefore mortality can be expected even under ideal conditions (Sea Lamprey Control Centre, pers. comm.). Dahl and McDonald (1980) indicated that Granular Bayer 73 and TFM could produce mortality in trout-perch and coregonids. Table 14 indicates that 10 Orders of invertebrates were identified, most predominant being a species of mayfly (Chessell, 1981) indicating that it was the most susceptible species affected by the lampricide treatment. The relative sensitivities of invertebrates to lampricide are listed in Table 14.

Although little significant information exists on the effects of lampricides on walleye at present the effects appear to be minimal. Lampricides do not appear to have any negative impacts on the life stages of the walleye nor do they seem to have any negative impacts on the walleyes main food sources.

Table 13. Individual stream treatment history, Canadian Lake Superior tributaries in the Nipigon Bay, 1958 to 1990.

Stream Name	Treatment Date	Km of stream treated	Treatment Flow cubic metre/sec.	TFM required	Bayluscide Wet. Powder	Bayluscide Granular	Kg of Active Ingredient
Cypress	Oct. 12,13/63	6.4	0.4	40.4			102
	Aug. 16,17/67	4.8	1.05	62.6	1.4		60
	Aug. 10,11/71	5.2	0.74	99.8		0.6	136
	July 9,10/75	5.2	0.99	116.1		0.05	117
	July 11,12/78	5.2	1.98	104.3			53
	July 17,18/82	5.2	2.83	137.9			49
	July 11,12/86	5.5	1.8				112.1
	July 6,7/90	5.5	84.7				
Jackfish	Sept. 23-29/60	14.5	0.74	336.1			457
	Sept. 5-8/64	9.7	2.15	412.8	9.5		192
	Sept. 18-23/69	11.3	1.27	235.9	4.1	1.4	485
	July 15-19/73	12.2	1.87	264.9	4.5	1.1	142
	July 11,12/77	10.6	6.29	549.3	6.8	0.4	87
	June 26,27/81	10	8.49	664.5	10.4	0.1	78
	July 11,12/84	9.8	7.09	690.3	8.7	0.3	97
	July 14-16/88	9.8	2.68		3.2	0.8	226
Nipigon	Oct. 4,5/64	12.9	108.79	15963.7	174.2		147
	Sept. 6-8/70	12.9	35.4	7832.2	203.7	0.5	221
	Aug. 3,4/75	12.9	50.46	6574.4	127	0.3	130
	July 2,3/81	12.9	67.56	7043.4	107.5	0.6	104
	Aug. 20,21/86	12.9	55	6652	101.13	0.13	
Lake Helen	July 8,9/83	2.42 ha				818.1	
	Aug. 11/85	0.73 ha				9.07	
	Aug. 19-21/86	3.71 ha				45.36	
Lower Nipigon	July 10,11/83	5	67.4	6187.4	99.1		92
Cash	Aug. 5-10/66	23.5	0.68	466.7	9.5		687
	July 18-21/76	25	1.08	367.4	6.8		342
	June 18-21/83	22.5	1.15	375.8			327
Polly	June 15,16/83	2.8	0.21	48.2			230
Polly Lake	Aug. 17/83	.88 ha			11.4		
	Aug. 12/86	66 ha				7.94	
Stillwater	Oct. 10-12/63	11.3	0.08	22.2			262
	Aug. 20,21/67	4.8	0.23	33.6		9	148
	Aug. 8-10/71	4.2	0.08	21.3			251
	July 16,17/75	8.1	0.23	62.1			274
	July 11-13/79	4.5	0.11	24.5			216
	June 12,13/83	4.5	0.29	49.3			170
Mountain Bay	July 17/82	1.5 ha				363	
	Aug. 13/85	1.8 ha				22.68	
Cypress Bay	July 18,19/82	1.9 ha				453	
	Aug. 15/86	1.7 ha				20.41	

* TFM, Wet Powder Bayluscide, and granular Bayluscide are measured in Kilograms of active ingredients.

Table 14. Species and numbers of invertebrates collected during lampricide treatment on the Nipigon River, 1981. Source: Chessell, 1981.

ORDER		# OF INDIVIDUALS COLLECTED
Ephemeroptera (Mayflies)		
Ephemerellidae		
1) Ephemerella (SS) invaria		1033
2) Ephemerella serratella or serratoides		22
Ephemeridae (Burrowing Mayflies)		
3) Hexagenia bileneata		7
4) Ephemera varia		5
Heptageniidae (Stream Mayflies)		
5) Heptagonia		3
Leptophlebiidae		
6) Leptophlebia		2
	TOTAL	1072
Plecoptera (Stoneflies)		
Chloroperlidae (Green Stoneflies)		
Hastaperla ? orpha		1
Perlodidae (Perlodid Stoneflies)		
Isoperla gibbsae/transmarina		95
Isoperla transmarina		1
Pteronarcidae (Giant Stoneflies)		
Pteronarcys pictetii/ dorsata		22
Pteronarcys dorsata		4
	TOTAL	123
Diptera (Flies)		
Ceratopogonidae (Biting Midges)		
Palpomyia/Bezzia		2
Chironomidae (Midges)		
Chironominae		
Chironomini Adult		2
Tanytarsini Pupal Execuvia		2
? Paracladopelma		1
Diamesinae		
Diamesa		4
Prodiamesa nir. fulva		1
Orthocladiinae		
Cricotopus bininctas		23
Eukiefferiella devonica q p		21
Simuliidae (Black Flies)		
Simulium ? rivuli		16
Tipulidae (Crane Flies)		
Antocha		3
	TOTAL	75

Table 14. Continued.

ORDER		# OF INDIVIDUALS COLLECTED
Trichoptera (Caddisflies)		
Hydropsychidae (Net-spinning Caddisflies)		
1) *Hydropsyche recurvata*		26
2) *Cheumatopsyche*		5
Glossossomatidae		
Glossasoma nigrior		7
	TOTAL	38
Hemiptera (Bugs)		
Corixidae (Water Boatmen)		
Sigara lineata	TOTAL	37
Oligochaeta (Worms)		
Tubificidae	TOTAL	4
Hirudinea (Leeches)		
Piscicolidae		
Pisicicola geometra	TOTAL	2
Coelenterata (Freshwater Sponge)		
Hydridae		
Hydra americana	TOTAL	2
Mollusca (Clams)		
Lymnaeidae		
Stagnicola catascopium f. nasoni	TOTAL	1
Odonata (Dragonflies & Damselflies)		
Gomphidae (Clubtails)		
Ophiogomphus columbrinus	TOTAL	1

9. DDT USE IN THE NIPIGON AREA

In the 1940's DDT was used in aerial spraying for the protection against spruce budworm and also as a pesticide in some localized areas until the mid 60's. The harmful effects of DDT were obviously not well documented at that time and its use has since been banned in Canada.

Because of the urgency of the budworm problem the Department of Lands and Forests continued its tests (on DDT) in 1945 on a much wider scale, using three R.C.A.F. Canso amphibious aircraft to spray two blocks of timber covering 64,000 acres southwest of Lake Nipigon (Lambert and Pross, 1962). This was the largest programme of its kind in the world at that time.

DDT was used in the community of Cameron Falls from 1945 to 1966 as part of a program to alleviate the black fly problem. This consisted of dripping DDT directly into the creeks in the vicinity to control the blackfly larvae.

A resident who worked on the program recalls it as follows:

> "It consisted of dripping DDT directly into any creek within eight kilometers of the community twice a week during black fly season. Most of the treated creeks were on the west side of the river, with Polly Creek the notable exception. Treatments took place at one station per creek for the smaller ones and more on the larger streams. Frazer Creek was the most heavily treated, with three stations. The objective of each treatment was to achieve a specified concentration of DDT in the water." (MacCallum, 1989).

> "At concentrations used for black-fly control at Hydro Electric construction and operations projects in Northern Ontario, DDT has appeared not to be immediately harmful to wildlife. Recent evidence has indicated, however, that DDT may have a cumulative deleterious effect on fish and aquatic organisms" (HEPC, 1966).

Total treatments for the Cameron Falls community amounted to 90 gallons per year of DDT EM-2 emulsifiable concentrate per year between 1945 and 1965 (German, 1968). In 1966, 45 gallons of DDT was applied by Ontario Hydro to several streams in the vicinity of Cameron Falls to control blackfly larvae.

At the time of the spraying and the use of DDT no short term effects were noted except for the disappearance of the blackflies. It was later determined that DDT is a chlorinated hydrocarbon insecticide of extremely stable composition. The use of DDT was discontinued in the late 1960's.

During German's study in 1966 and 1967, 11 white suckers were tissue sampled for DDT residues. Low levels of DDE (<1.0 ppm) were detected in the body tissues of each of the fish analyzed. German notes, however, that no hazard would be anticipated from consumption of fish containing these relatively low levels of DDE, nor would the natural reproductive capacity of these fish be affected on the basis of information available. It is recognized that residues are concentrated to the greatest extent in the fatty tissues of fish. Assuming that walleye concentrate DDT in a similar manner and to an equal or lesser extent than the white sucker, which is reasonable considering the greater proportion of fatty tissue present in suckers, it is unlikely that the DDT black fly control programme at Cameron Falls would have been responsible for the disappearance of walleye in Nipigon Bay (German, 1968).

10. TRADITIONAL SPAWNING SITES

Suitable walleye spawning habitat (Scott and Crossman, 1973) consists of rocky areas in white water below impassable falls and dams in rivers, or boulder, to coarse-gravel shoals of lakes. Fish often move into tributary rivers as soon as the rivers are ice free. Spawning takes place at night. This could account for the lack of actual observations from the local anglers. Walleye are tolerant of a wide range of environmental conditions but seem to thrive best in large, shallow, turbid lakes. Movements involve a spring spawning run to shallow shoals or tributary rivers, daily movements up and down in response to light intensity, and daily or seasonal movements in response to temperature and food availability (Scott and Crossman, 1973).

Information regarding the traditional spawning beds of the walleye in Nipigon Bay was gathered from all available sources including journal documentation and interviews with local residents. Several possible spawning beds are noted by the interviewees but actual sightings during spawning were very few. Information regarding the presence of large numbers of walleye in specific locations was often uncovered but this did not necessarily correspond with the walleye spawning period. R. A. Ryder, a fisheries scientist who conducted studies on Nipigon Bay from 1955 to 1958, was also interviewed.

The Nipigon River below the Highway Bridge

Skillen (pers. comm.) noted "millions" of walleye moving under the highway bridge on their migration to Polly Lake, Lake Helen, and Steamboat Bay. He notes that the walleye were so numerous that they were like diamonds in the water in the 1950's. Skillen (pers. comm.) recalls that the last two walleye they caught in Lake Superior was in 1967.

McInnes and Matchett (pers. comm.) also suggests the highway bridge as a possible site for spawning walleye.

Dampier (pers. comm.) knows that the walleye were present under the highway bridge but he thinks that it may have been before spawning had taken place as it was often prior to ice out.

Dupuis (pers. comm.) used to walk the Nipigon River and observe the spawning walleye before their population collapsed in about 1965. He indicates the east shore of the Nipigon River below the highway bridge and also the point north of Gapen's Pool had so many walleye that all one noticed was a "sea of eyes". The walleye were present in the lower river in the spring and also in the first half of August. During the fall run, fishing was tremendous from the exit of Lake Helen all the way up to the Chalet Lodge. Dupuis was out fishing one evening in late July 1953 with Dan Gapen when both caught 60 fish on 60 casts on the point above Gapen's Pool.

According to Ryder (pers. comm.) the only definite site where walleye were observed to be spawning was under the Nipigon highway bridge. He also notes that although this is the only one they found it doesn't necessarily mean that it was the only one. Ryder feels that the other areas where walleye were observed (Clay Banks, Polly Lake, Lake Helen etc.) were not spawning grounds but were rather areas where the fish were congregating subsequent to spawning.

Upper Nipigon River

Dupuis (pers. comm.) observed that the walleye were once plentiful at Parmacheene and in the eddies of the river.

Clay Banks

Skillen and Dupuis (pers. comm.) feel that the Clay Banks were a spawning site for walleye that were utilized by commercial fishermen who in turn depleted the stock of walleye located there.

Dampier (pers. comm.) illustrated spawning shoals on Nipigon Bay from Five Mile Point south along the Clay Banks and also from the Ruby Creek inlet west past Hughes Point on the northern shore of the bay. He also notes that his father fished for walleye using pound nets at Caribou Point (on St. Ignace Island).

Steamboat Bay

Many residents thought that Steamboat Bay could be a potential walleye spawning site (Skillen, Dampier, pers. comm.).

Polly Lake

Skillen and Dupuis (pers. comm.) recalled that the walleye fishing was excellent in Polly Lake and that it might be a spawning site. Ryder (pers. comm.) also checked for spawning activity in Cash Creek which flows into Polly Lake but no walleye were seen.

Lake Helen

McInnes (pers. comm.) doesn't know of any definite sites but suggests the shores of Lake Helen due to suitable habitat and an abundance of walleye in the past under the log booms.

Dupuis (pers. comm.) noted that the walleye were not as plentiful in Lake Helen as in Polly Lake because of the clearer, shallower water.

Stillwater Creek

McInnes (pers. comm.) notes the presence of suitable gravel in the Stillwater Creek that may have been used by spawning walleye in the past. He also reveals that a saw mill used to be located near the mouth of the Creek and that a large amount of sawdust, bark, and boom ends are still noticeable in the water.

Jackfish River

Dampier (pers. comm.) indicates that the walleye spawned in the Jackfish River but he doesn't know how far upstream. Skillen (pers. comm.) noted that there was excellent large walleye fishing on this river all the way up to the mouth of Limestone Creek.

The Jackfish River had thousands of walleye in it during the spawning run (Dupuis, pers. comm.).

Ryder (pers. comm.) feels that the Jackfish River has potential as a spawning site but there is no evidence of it. He knows that the walleye were often found in this river in August, two or three months after spawning had occurred. Possibly, the fish travelled up the Jackfish after spawning.

Ozone Creek

Dupuis (pers. comm.) recalls that his father used to fish in this creek many years ago. He also notes that Kama Bay (which the Ozone flows into) was closed to commercial fishing of walleye for many years. This is a potential walleye spawning site.

CONCLUSIONS REGARDING SPAWNING SITES

One spawning site of walleye which has been positively identified is under the highway bridge on the lower Nipigon River and the observers are Ryder and Ray Dupuis. This location was observed from 1955 to 1960 and every few years after by Ryder. Dupuis would also watch for spawning walleye every year. He stopped searching about eight years ago because they just weren't there anymore but prior to that he was there every year for 25 years. The west shore of Nipigon Bay, known as the Clay Banks, has been identified by commercial fishermen who were able to catch walleye while they were congregating in the spring. This congregation is believed to be a movement towards available food rather than a spawning congregation. The prevailing west winds would bring in an abundant supply of food for the walleye. Ryder was aware of the other areas in which the walleye were noted and he considered them to be part of a migration route used by the walleye (Ryder, 1968). Walleyes tagged in the lower Nipigon River in 1955-57 showed similar seasonal movements from year to year.

Walleyes on the Nipigon River spawning grounds in May during these three years reappeared on the spawning grounds one year later, almost to the day. Scott and Crossman (1973) state that there is evidence of homing behavior to spawning grounds in walleye year after year. Concentrations of walleyes at the northwest corner of Nipigon Bay, the Clay Banks, and Polly Lake also occurred about one year apart suggesting a dispersal which was repeated annually (Ryder, 1968). Ryder (1968) observed that walleye were first encountered in the Nipigon River in late April before spawning, which usually took place in early May near the townsite of Nipigon. Shortly after spawning they left the vicinity of the spawning grounds and dispersed: 1) upstream through Lake Helen and into Polly Lake, which some fish reached in late May, the majority by June; 2) downstream to Nipigon Bay. In the downstream movement, the first fish arrived at Five Mile Point in Nipigon Bay by late May and followed the west shore in a southerly direction. By the end of June walleye in the downstream movement were widely distributed in the shallow west end of Nipigon Bay and some of its tributaries on the north shore. This migration pattern illustrates most of the areas in which local residents found successful fishing for walleye.

FIGURE 17. POSSIBLE SPAWNING LOCATIONS OF WALLEYE IN NIPIGON BAY AND LAKE SUPERIOR TRIBUTARIES AS INDICATED BY LOCAL ANGLERS AND M.N.R. PERSONNEL.

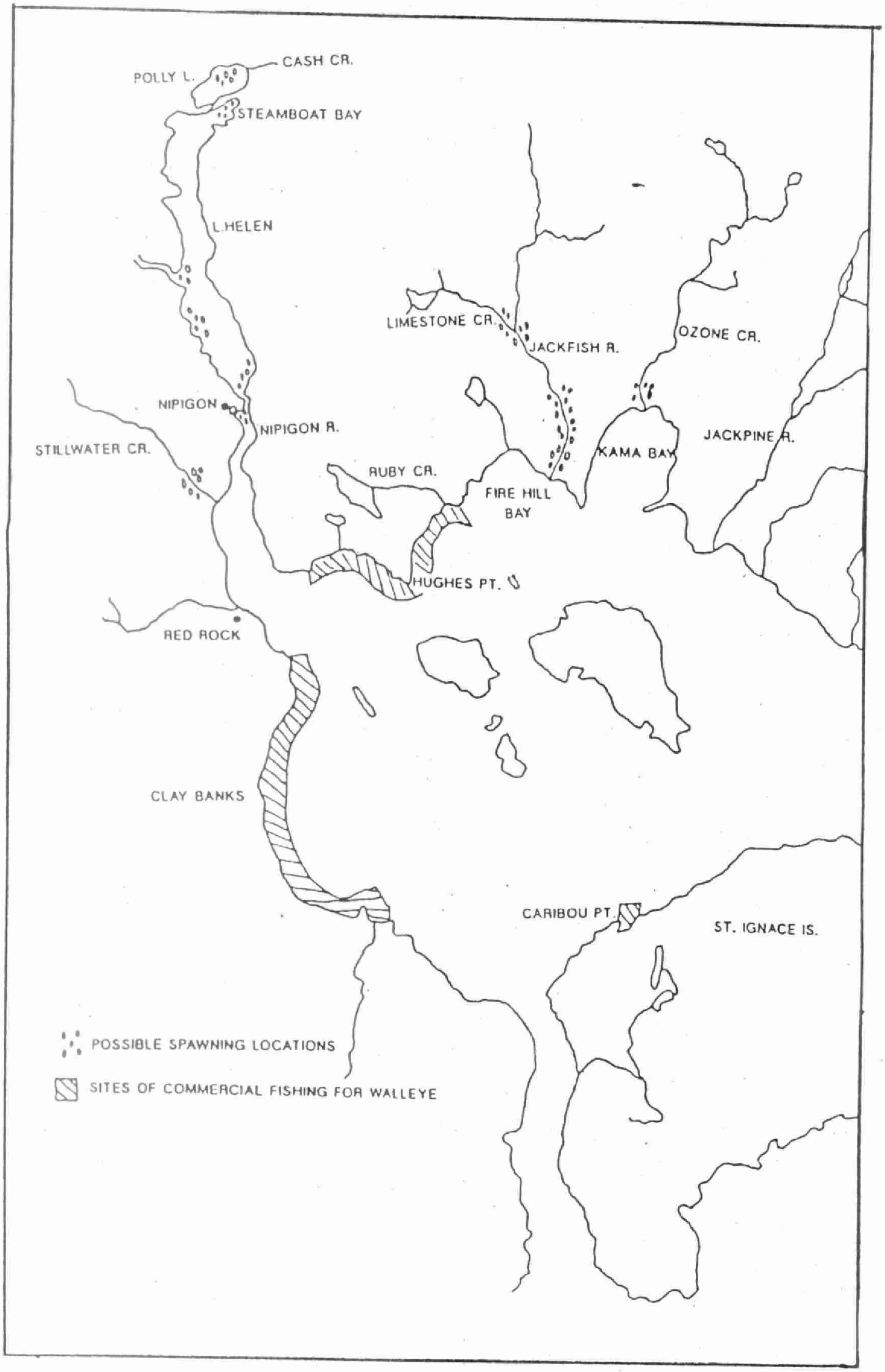


FIGURE 18. IDENTIFIED SPAWNING LOCATION OF WALLEYE IN NIPIGON BAY.

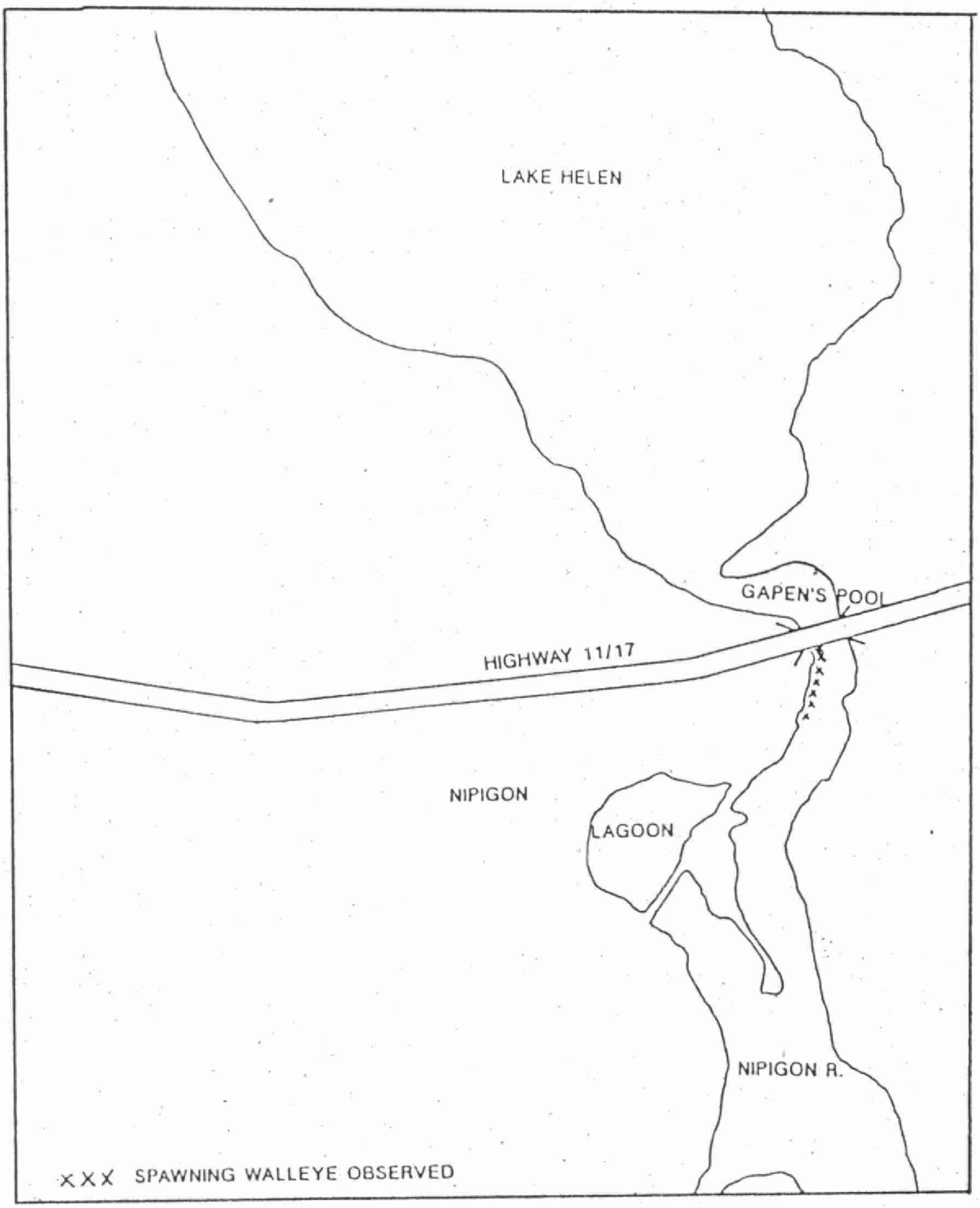


Table 15. Summary of walleye stocking in Nipigon Bay.

Date	Development Stage at Stocking	Number Stocked
1978	eggs	261 000
1979	eggs	1 170 000
1980	eggs	1 364 000
	fingerlings	20 800
1981	eggs	500 000
	fingerlings	3 700
1982	eggs	1 461 000
	fingerlings	11 755
1983	eggs	2 450 000
	adults	347
1984	fertile eggs	350 000
	eyed eggs	200 000
	fry	757 000
1985	fry	4 000 000
	fingerlings	1 800
1986	fry	425 000
	adults	556
1987	adults	421
1988	adults	932
1989	adults	777
1990	adults	3 500

Source: Nipigon District stocking records - walleye file
Fish and Wildlife Annual Reports 1977 - 1984

11. STOCKING AND REHABILITATION

An attempt to re-introduce walleye into Nipigon Bay began in the spring of 1978 with the planting of green eggs in the Jackfish River. Eggs were chosen in order to re-establish a viable, self-reproducing population. The eggs were taken from Current River on Lake Superior and were planted approximately 8 km upstream from the mouth of the Jackfish River in an area dominated by alternating gravel riffles and pools (Walroth, 1980). This area is located downstream from the area where Limestone Creek enters the Jackfish River. The Jackfish River to the mouth of the Limestone Creek was quoted was having great walleye fishing in the summer (pers. com. Roe Skillen). Ray Dupuis (pers. com.) also noted that the Jackfish River had thousands of walleye in it at one time. It is not known whether the walleye actually spawned in the Jackfish River or whether they were simply migrating in a congregation after spawning in another location on the bay. Ryder (pers. com.) noted that a resident population of walleye existed in the Jackfish River during the 1950's but there is no evidence that walleye were spawning at this site. Ryder suggests that it has suitable substrate. A heavy deposition of smelt eggs occurred in this section of the river in 1978 along with the 500,000 walleye eggs that were fertilized, transported and deposited (Walroth, 1980).

In 1979, the program was continued with 1,170,000 eggs fertilized and released randomly over the substrate. No follow-up studies were conducted to determine the hatching success of these introductions. Gillnetting was conducted during the spring and summer on the Jackfish River to document the presence or absence of residual walleye from Nipigon Bay or from the river proper that may have been using the river for spawning. No walleye were captured.

Egg transfers occurred again in 1980 with a total of 1,364,000 eggs being fertilized and deposited over gravel rubble on the Jackfish River. Fry traps were put in place to measure hatching success. A drop in the water level of the river of approximately 1 m effectively ended the attempt to quantify percent hatching success due to the small amount of water passing through the fry traps. The fluctuating water levels probably had some effect on the actual hatching of the walleye eggs. Low water levels could result in the desiccation of the incubating walleye eggs while high levels could cause them to become swept downstream. Predation by the smelt present on the site of the stockings may also have affected the success of the eggs.

The egg transfer program was continued in 1981 using Onaman Lake walleye as the source of eggs rather than the Current River. The problems experienced in the past with widely fluctuating water levels causing extensive egg mortality were averted with the placement of eggs in midstream instead of near the shore. Approximately 500,000 eggs were introduced in 1981.

In 1983 eggs were collected from Onaman Lake. The eggs were fertilized on site and transported to the stocking sites. At the stocking sites the eggs were distributed over appropriate spawning substrate from shore and from a boat. In all, approximately 2,500,000 fertilized eggs were distributed to four stocking sites (Jackfish River, Condon Island, Nipigon River at the Lake Helen public access, Nipigon River at the highway bridge).

A test netting program was carried out in August 1983 in Fire Hill Bay, near the mouth of the Jackfish River to assess the success of green walleye egg introductions (Table 16). Nine walleye were captured. Electrofishing was also conducted in the same area yielding one walleye (Table 17).

A walleye egg stocking program was initiated by the Red Rock Fish and Game Club and the Ministry of Natural Resources as part of the Community Fisheries Involvement Plan in 1984. Eggs were collected from the Current River, Onaman Lake, and Lake Nipigon. A jar hatchery constructed at the fish and game club was used for incubation of the eggs. Almost all of the early hatch of fry went into Trout Creek immediately after hatching. After hatching was underway, eggs and fry were measured into seed lots and placed in plastic bags for the transfer to the ponds. Little success was realized in fry recovery from any of the ponds (Furlong, 1984).

In 1985 approximately 3,681,000 fry and 1,835 fingerlings were released into the Nipigon Bay near the mouth of the Nipigon River. the eggs were obtained from Lake Nipigon. Index gillnetting was conducted in 1985 at five net sites as part of an assessment plan to determine the success of the stocking program. No walleye were caught (Table 16).

In 1986, an assessment plan was initiated in Nipigon Bay to determine the success of the walleye rehabilitation efforts. One trap net set in the Nipigon lagoon yielded 1304 fish of which only one was a walleye (Table 18). The walleye captured was a female that was considered to be still "green" at the end of the spawning season. The ministry staff suggest that resorption of the eggs may have occurred. The catch was predominantly yellow perch and common white sucker (Nipigon District files, 1987). A trap net set in Stillwater Bay captured 1714 fish but no walleye. Index gillnetting in June and July produced no walleye. Based on the data collected, there has undoubtedly been no increase in the walleye population. Local residents still catch the odd walleye in the area, perhaps indicating a small walleye population in Nipigon Bay (Nipigon District files, 1987). Seining was also conducted in Firehill Bay, Kama Bay, and across from the Nipigon dock but no young of the year walleye were captured. Index netting was continued in Nipigon Bay through 1986 and 1987 to include contamination sampling. No walleye were captured in Nipigon Bay but a test net set in Lake Helen yielded 10 adult walleye (Nipigon District files). Electrofishing in Nipigon Bay in 1986 yielded

several species indicative of good water quality (i.e. whitefish, natural rainbow and brook trout) but no walleye were collected (B.A.R. Environmental, 1986). Electrofishing was more extensive in 1987 but still no walleye were captured.

In 1986 the adult walleye transfer program began in Nipigon Bay. The source of the 556 adult fish was Savanne Lake in the Thunder Bay District. The fish were moved to Nipigon by truck or aircraft in an oxygenated tank. Transfers took place in both spring and fall when preferred lower water and air temperatures would minimize handling stress. This program continued in 1987, 1988, and 1989 with 421, 932, and 777 adult fish being transferred respectively.

The adult walleye transfer program in 1990 was one component of the Remedial Action Plan program whose goal is to rehabilitate pollution damaged areas in the Great Lakes. It was deemed an appropriate time to try to re-establish the walleye population since many of the suspected factors contributing to their decline in the early 1960's have been eliminated. Effluent loadings from industry and the townships has declined, sea lamprey populations are reduced, the commercial fishery in the western portion of Nipigon Bay has been discontinued (1984), and the angling fishery for walleye has been closed in Nipigon Bay, Lake Helen, Polly Lake and the lower reaches of the Nipigon and Jackfish Rivers (1989). 3500 adult walleye were stocked in Nipigon Bay. These fish were purchased from commercial fishermen fishing on Lac des Mille Lacs. The fish were transferred using both aircraft and tanks on trucks (Nipigon District files).

A total of 11,000 fish are to be transplanted in a three year period. Starting in 1991 an ongoing assessment of the success of the project will begin. It is hoped that the rehabilitation will be successful and that walleye will once more be a major component of the Nipigon Bay fish community.

Table 16. Summary of gillnetting results, Nipigon Bay.

	1983	1985	1986*	1987
Alewife	6	260	48	16
Rainbow Trout	1	2	4	26
Brook Trout	5	0	11	6
Lake Trout	0	0	3	49
Lake Whitefish	1	56	126	174
Cisco	0	0	16	1
Round Whitefish	5	13	129	228
Lake Chub	0	3	0	10
Rainbow Smelt	0	53	9	1459
Northern Pike	3	0	0	0
Longnose Sucker	5	61	126	264
White Sucker	234	386	457	583
Carp	4	0	0	0
Spottail Shiner	30	0	0	54
Pearl Dace	4	0	0	0
Burbot	0	0	0	13
Trout Perch	21	0	0	0
Yellow Perch	354	217	287	603
Walleye	9	0	0	0
# fish / # species	662 / 14	168 /9	1216 / 11	3486 / 14
Total Netting Time (h)	340	100.75	229.5	472
Length of Net (feet)	2600+	2500	5000	10550

* Source: Nipigon District files

Table 17. Summary of electrofishing results, Nipigon Bay.

	1983	1986	1987
Sea Lamprey	0	3	1
Alewife	0	9	8
Chinook Salmon	0	0	7
Rainbow Trout	0	16	5
Brook Trout	0	1	1
Lake Trout	0	0	5
Lake Whitefish	1	1	8
Round Whitefish	0	2	112
Lake Chub	0	3	4
Rainbow Smelt	0	19	125
Longnose Sucker	0	19	41
White Sucker	17	24	100
Shorthead Redhorse	0	0	1
Sucker spp.	0	0	1
Carp	0	1	0
Emerald Shiner	0	2	4
Spottail Shiner	86	25	105
Burbot	0	2	7
Brook Stickleback	0	1	3
Ninespine Stickleback	0	0	3
Trout Perch	294	5	233
Yellow Perch	58	19	137
Least Darter	0	0	1
Johnny Darter	1	0	3
Logperch	0	0	1
Mottled Sculpin	0	3	22
Slimy Sculpin	0	1	4
Mottled x Slimy Sculpin	0	2	0
# fish / # species	457 / 6	158 / 20	942 / 26
Effort (seconds)	6000	4600	15070

* Source: Nipigon District files and Dalziel, 1988.

Table 18. Summary of trap netting results, Nipigon Bay.

	1986	1987
Sea Lamprey	2	0
Rainbow Trout	57	24
Brook Trout	1	6
Lake Trout	1	3
Lake Whitefish	106	19
Cisco	3	2
Round Whitefish	33	15
Rainbow Smelt	1	2
Northern Pike	5	1
Longnose Sucker	162	117
White Sucker	1680	1530
Redhorse Sucker	10	12
Burbot	10	3
Yellow Perch	946	319
Walleye	1	3
# fish / # species	3018 / 15	2062 / 14
Time Set (hours)	432	504

* Source: Nipigon District files

12. COMMUNITY CHANGES

Historical catch statistics reveal that the fish community of the past consisted largely of lake herring and lake trout. These two species composed 57% and 34%, respectively, of the total harvest in Nipigon Straits and Bay in 1912 (Figure 19). The harvests of 1961 reveal the increased importance of lake whitefish and the abundance of walleye at that time. Figure 20 illustrates the commercial catches of walleye from Michigan, Wisconsin, and Ontario waters of Lake Superior. The walleye decline is evident in all areas although the time periods are varying.

Presently, the Nipigon Bay fish community has a relatively low level of diversity and is dominated by lake whitefish and mullet (common and longnose sucker). In-shore areas are dominated by mullet and yellow perch along with various warm water and forage fish species. Common and longnose suckers completely dominate the community structure adjacent to the kraft mill effluent at Red Rock (Kelso, 1977). Many inlets into Nipigon Bay support seasonal rainbow trout and rainbow smelt runs as well as spawning and nursery habitat for migratory chinook salmon, coho salmon, pink salmon, coaster brook trout, brown trout, sucker and whitefish (Vander Wal, 1989).

12.1 PERCH

The changes in the yellow perch population are discussed here as a possible competitor to walleye for food and space. The increase in the perch population seems to correlate with the decline in the walleye population. In 1974, the perch production in Nipigon Bay had increased by 4500% from the previous year. In 1976, anglers claimed that the numbers of perch were decreasing and that the cause was overfishing by commercial fishermen (Walroth, 1979). In 1977, a peak harvest of 10,136 kg of perch were taken (Vander Wal, 1989). The perch fishery declined steadily remaining significant only until 1982. Scott and Crossman (1973) note that the perch's high reproductive potential, voracious appetite, and effectiveness at feeding can in some places lead to serious competition with more valued species. Data is not extensive enough to make any predictions on the effect of the perch community on the walleye in Nipigon Bay.

12.2 INTRODUCED SPECIES

The effect of introduced species is impacting on the native species of Nipigon Bay by occupying former niches and competing for available forage. The effects of predation and competition by these alien species is difficult to assess.

Rainbow smelt became established in Lake Superior in the 1930's, but did not become abundant until the 1950's. Smelt abundance increased in the 1950's, and by the early-1960's smelt

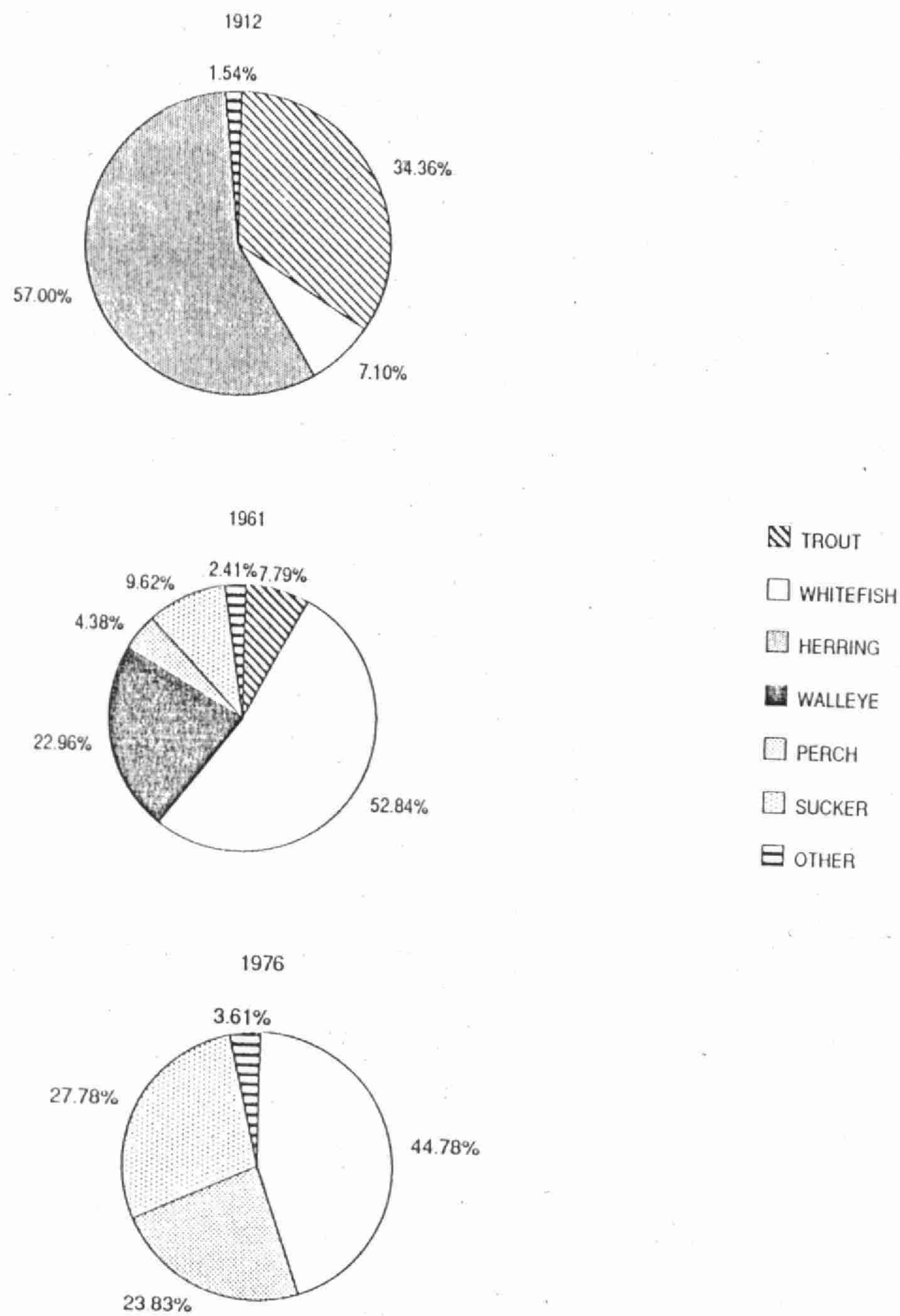
had become the major food of lake trout. Smelt abundance declined sharply in the late 1970's and partially recovered by the mid-1980's. Recent information indicates that smelt remain the major food item of lake trout in Lake Superior and herring are of a secondary importance. Smelt are voracious, and could have a severe impact on fish communities in which they are not native and which are being subjected to other stresses (Schneider and Leach, 1977). A seemingly small effect of individual smelt on pelagic larval walleye, or their food, would be magnified greatly at the population level because smelt attain high densities. On the other hand, both species now coexist in certain areas of the Great Lakes and in certain inland lakes (Schneider and Leach, 1977). The stresses on the walleye stocks of the Great Lakes, including the effects of alien species, are noted in Table 20. Stresses more specific to Nipigon Bay are listed in Table 19.

The alewife was first noted in Lake Superior in 1945. It has been speculated that the alewife explosion in the other Great Lakes (particularly Lakes Michigan and Huron) has not occurred in Lake Superior due to lower water temperatures or predation by lake trout and other large predator species (Scott and Crossman, 1973). The alewife has become an important food for walleye in the Great Lakes and any adverse impacts on the walleye are unknown (Schneider and Leach, 1977). Alewife were present in the gillnetting studies conducted on Nipigon Bay in 1986 (Table 16).

The sea lamprey were first noted in Lake Superior in 1938 but did not seriously affect the fish stocks until the mid 1950's. The sea lamprey introduction into Lake Superior had a significant impact on the lake trout in the fish community but its impact, as a predator, on the walleye appears to be minimal. Ryder (1968) found that only 1% of the walleye captured during his 1955-58 study had lamprey wounds. Farmer and Beamish (1973) indicated that the walleye is low on the lamprey's preference list.

Coho salmon and chinook salmon have co-existed with walleye in Lake Superior for over 20 years, yet there is no evidence that salmon have had an adverse impact on walleye. The salmon may not be directly competing with the walleye due to different seasonal distribution (Schram et al., 1991).

Figure 19. Composition of the species commercially harvested in Nipigon Bay for the years 1912, 1961, and 1976.



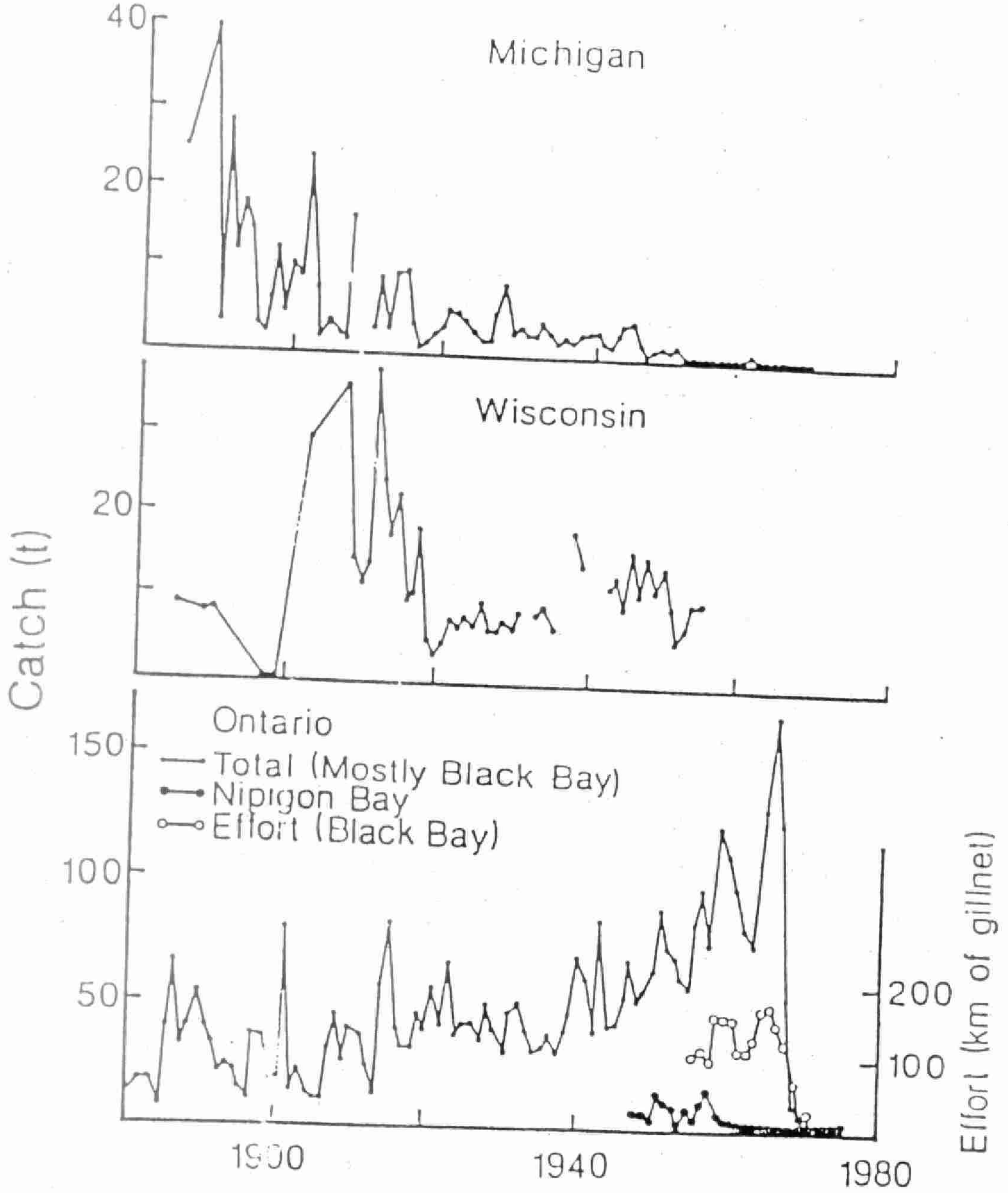


FIG. 20. Commercial catches of walleyes from the Michigan, Wisconsin, and Ontario waters of Lake Superior, 1880–1975, and fishing effort at Black Bay, 1956–75.

14. CONCLUSIONS AND RECOMMENDATIONS

The walleye decline in Nipigon Bay, Lake Superior, in the 1960's and its subsequent collapse was probably a result of a combination of many detrimental factors. Various sources of stresses, including high exploitation, pollution, habitat alteration, and the introduction of alien species, have all affected the reproductive capacity of the walleye.

The walleye congregated on the west shore of Nipigon Bay in a predictable migration every year making it extremely easy for the commercial fishermen to locate them. The effects of overexploitation would be intensified on this discrete stock of walleye. The drastic decline is noted in the commercial catch statistics from Nipigon Bay. The population, dominated by older individuals, was slow growing and therefore less able to absorb the impact of intensive fishing (Schram et al., 1991).

Many habitat alterations have taken place in Nipigon Bay. In general, Nipigon Bay is not the ideal turbid, warmwater environment favoured by the walleye. Combined effects of deforestation, damming, and industry have resulted in increased sedimentation and warming of water in the normally austere environment. Perhaps the walleye have not necessarily declined, but have, in fact, returned to a natural state following a period of unusual abundance.

Ryder (1968) concluded that industrial pollution from the Red Rock mill, rather than overexploitation, dispatched the walleye in Nipigon Bay. Ryder (pers. comm.) states that the effluent plume created a barrier to the natural migration route of the Nipigon Bay walleye stock rather than directly affecting the physical ability of the walleye to reproduce. Studies conducted in 1977 showed that the pelagic larvae of other species that spawn upstream from the mill were not adversely affected by the effluent plume (Leslie and Kelso, 1977). Effluent from the mill may indirectly affect the walleye by adversely affecting its food sources. The benthic community was found to be degraded in abundance and species distribution in the vicinity of the mill outfall (Vander Wal et al., 1989).

Climatic factors may have an effect on the reproductive success of the walleye if the species is already subject to a number of stresses. The low water levels in the 1960's may have contributed to a series of weak year classes. Spawning may not take place if the temperatures are unusually high or low (Scott and Crossman, 1973). Resorption of eggs is known to occur in walleye if the spawning conditions are not favourable.

The alterations taking place in the fish communities of Lake Superior have been drastic in the last 50 years. The effect of lamprey predation on walleye is not significant but its effect on the other more preferred species is very evident. The impact of

lamprey predation on the whole aquatic ecosystem as it relates to changing species dominance must be considered. The electric lamprey weir operated on the Jackfish River in 1959 apparently resulted in the electrocution of only a small percentage of the walleye occupying Nipigon Bay at that time (Ryder, pers. comm.). Seelye et al. (1987) found that the early life stages of the walleye were considerably more resistant than sea lamprey ammocoetes to the lampricide TFM making it unlikely that chemical control had any adverse affects on the walleye population.

Although stocking has taken place since 1978, there appears to be little success. In order to increase the success of the introductions, spawning sites must be upgraded or created so those walleye stocked will begin to reproduce. The one positively identified historic spawning site is still present but the substrate is covered with algae making it unsuitable. Scrubbing off the algae or removing the source of nutrient loading upstream from the site may result in a return of the walleye. Sonic tagging would result in documentation of stocked walleye movement to determine if these adult fish remain in Nipigon Bay. Mortality of the transferred adults should be tested using a holding pen at the transfer site.

This report attempts to identify the major sources of stress responsible for the walleye decline in Nipigon Bay, Lake Superior (Table 19). With the stresses identified, a management plan can be developed to either reduce or eliminate them.

The closure of Nipigon Bay to commercial fishing in 1984 and the closure of Nipigon Bay and River to angling in 1989 will alleviate one of stress factors that affected the walleye population. This closure should remain in place until there is evidence of a viable, reproducing walleye population.

Table 19. Stresses affecting the walleye population in Nipigon Bay, Lake Superior.

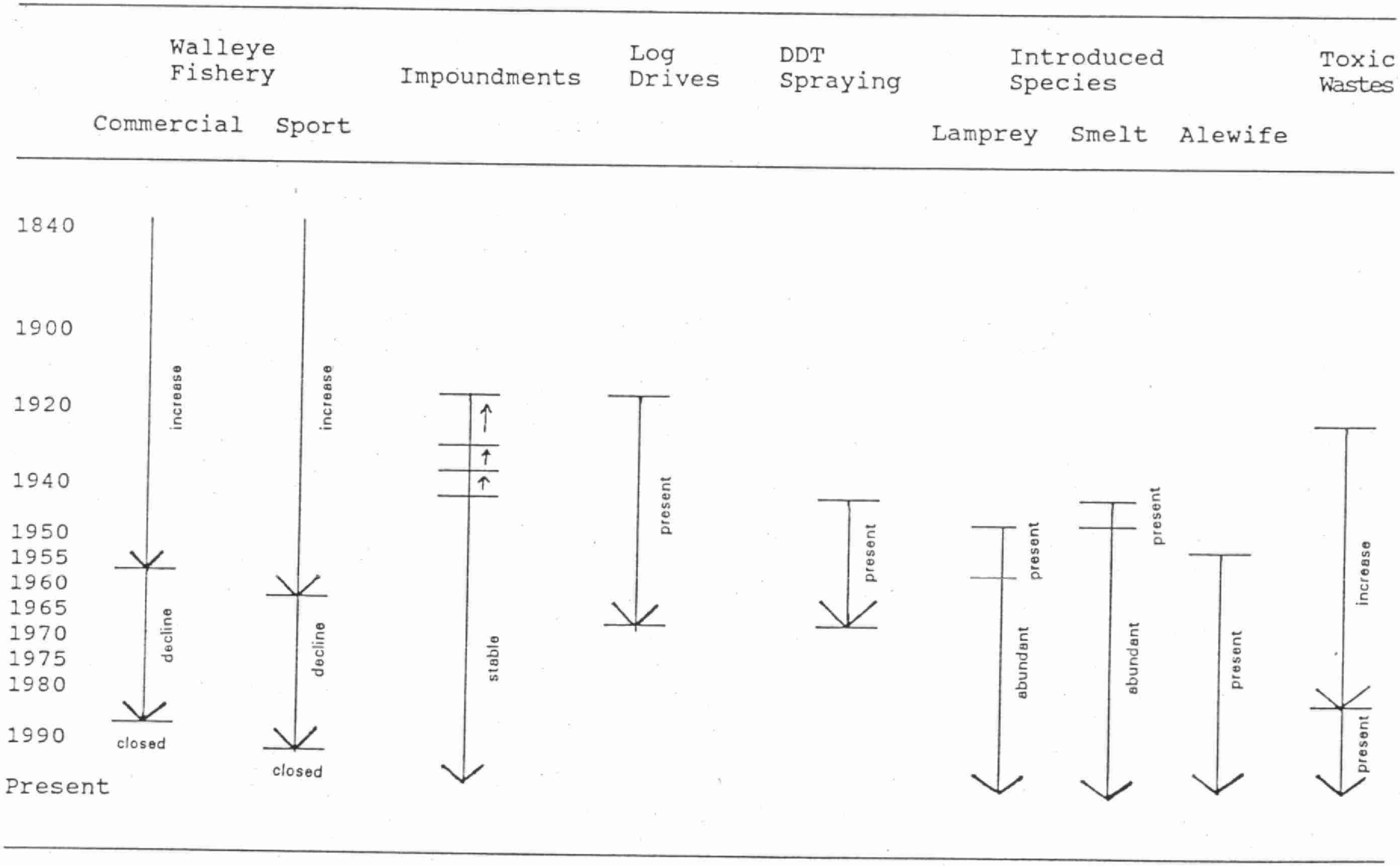


Table 20. Summary of stresses affecting walleye stocks in the Great Lakes, and approximate dates of major population declines.

Stock	Year of major decline	Source of Stress								
					Alteration of spawning habitat		Alien species			
		Exploitation	Nutrient loading	Toxic materials	Sedimentation	Restructuring	Smelt	Sea lamprey	Alewife	White perch
Lake Superior										
Black Bay	mid 1960's	XX					P	P		
Nipigon Bay	late 1950's	X?		XX			P	P		
Michigan	Gradual 1900's	XX?					(P)	(P)		
Wisconsin	None						P	P		
Minnesota	late 1800's	XX	(P)	(P)	(P)		(P)	(P)		
Lake Michigan										
Green Bay										
Northern	1953	X	P				X	P	XX	
Southern	Gradual 1920's	X	X	P	XX	XX	X	(P)	(P)	
Eastern	Mid 1950's	P	P	P			P	P	XX	
Lake Huron										
Saginaw Bay	1944	X	XX	P	XX	P	(P)	P	X	
Au Sable R.	late 1800's	P			XX	X	(P)	(P)	(P)	
Thunder Bay R.	Gradual 1920's	P			XX	X	P	(P)	(P)	
Northwestern	None	P		P	P	P	P	P	P	
North Channel	Gradual 1930's	P		X	X	P	P	P	P	
Georgian Bay	None	P					P	P	P	
Lake Erie										
Western	1955	XX	XX	P	X	X	X	P	P	P
Eastern	None	P	P	?			P	P	P	P
Lake Ontario										
Bay of Quinte	1960	P	X	?	P		P	P	P	XX
New York	Gradual 1920's	XX?	P	?	X?	?	(P)	P	P	(P)

* XX = major factor in the decline; X = minor factor in the decline; P = present; (P) = not important factor in the decline but may have prevented recovery of the stock.

** Source: Schneider and Leach, 1977.

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Appendix A. A Chronological Review of the Stresses Affecting the Fisheries in Nipigon Bay, Lake Superior.

1839
- Hudson's Bay Company fishing on a commercial scale, Red Rock one of the seasonal posts

1877
- five commercial licences on Nipigon Bay

1900
- walleye was considered a coarse fish and it was removed in order to enhance the trout population on the Nipigon R.

1908
- Nipigon River channel was deepened using a dredge to facilitate larger freighter laden with rails

1912
- CNR completed through Nipigon

1920
- Cameron Falls generating station constructed on the Nipigon River

1923
- log drives began on the Nipigon River (continued until 1973)

1930
- Red Rock kraft mill established as sulphite pulp mill in the late '30's, production 60 tons/day
- walleye the most abundant fish on the river in the 1930's
- Alexander dam completed on the Nipigon River for hydro-electric power generation

1940
- during this decade, DDT was used in aerial spraying for protection against the spruce budworm and as an insecticide in some localized areas until the mid '60's
- smelt present in Nipigon Bay but not yet abundant

1950
- Red Rock mill changed to kraft production, production 390 tons/day
- Pine Portage dam constructed resulting in considerable flooding on Nipigon River
- local residents report excellent walleye fishing in the 1950's

1943
- Ogoki diversion construction increased the water available for power generation on the Nipigon River by 50% (from 8000 to 12000 cubic feet per second)

Appendix A. Continued.

1950
- smelt population had become abundant in Lake Superior

1955
- old kraft machines were partially converted to semi-chemical sulphite pulp production
- 90 walleye tagged in the lower Nipigon
- 1955 to 1958 abundant number of spawners
- sea lamprey had begun to seriously affect the fish stocks in Lake Superior

1956
- thousands of walleye noted in the lower Nipigon during May 1000 tagged

1957
- estimated walleye population in the Nipigon R. spring spawning run to be 22,000 individuals; the fall estimate in Nipigon Bay was 41,000

1958
- a bleach plant and chemical recovery unit was added to the mill
- during 1955-58, 2200 walleye were tagged with 397 recaps indicating the possible migration routes and spawning locations

1959
- walleye are common but not abundant enough to provide numbers for tagging in 1959-60
- electrical sea lamprey barrier in operation on the Jackfish River

1960
- 67 tons of suspended solids was discharged into Nipigon Bay per day
- lampricide use began in the Nipigon area

1961
- tainting of commercial fish, whitefish caught in Nipigon Bay rejected due to objectionable taste
- walleye were scarce on the Nipigon R. spawning grounds

1964
- lower Nipigon river treated with TFM and Bayer 73

1965
- crash of Black Bay walleye population

1966
- study carried out by German (1968) to investigate complaints regarding tainting of fish flesh

Appendix A. Continued.

1973
- log drives discontinued in the Nipigon area

1975
- compared with peak years the commercial catch of walleyes in Lake Superior is down 88 - 100%, yellow perch by 34 - 86% and blue pike by 100% (Schneider and Leach, 1977)

1978
- an attempt to re-introduce walleye began with the deposition of walleye eggs into the Jackfish River

1984
- commercial fishing for walleye was closed in Nipigon Bay
- walleye incubation program started at the Red Rock Fish and Game Club

1986
- adult walleye stocking program began in Nipigon Bay

1989
- the Nipigon Bay, the Nipigon River, and the Jackfish River were closed to walleye angling year round to assist rehabilitation efforts